PN-ABL-623
ISN 77957

RESOURCE MANAGEMENT ASSOCIATES
of Madison, Inc.

ENERGY EFFICIENCY AUDIT REPORT

VILNIUS SWEETS PLANT
Vilnius, Lithuania

JUNE 1992

PREPARED BY: RESOURCE MANAGEMENT ASSOCIATES OF MADISON, INC.
Madison, WI

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN AND CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
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U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
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OFFICE OF DEVELOPMENT RESOURCES
ENERGY & INFRASTRUCTURE DIVISION
WASHINGTON, D.C. 20523
USAID Contract EUR-0015-C-1006-00

Table of Contents

i. Industrial Energy Efficiency Program 1

ii. Executive Summary 3

1.0 Plant Description 6
- 1.1 General Energy Utilization 6
- 1.2 Organization 6
- 1.3 Electrical System 8
- 1.4 Thermal System 11
- 1.5 Process Description 13

2.0 Plant Energy Profile 15
- 2.1 Gas Consumption and Steam Production 15
- 2.2 Electric Consumption 15
- 2.3 Energy Costs 22
- 2.4 History of Energy Efficiency Measures 23

3.0 Energy Audit Description 29
- 3.1 Summary 29
- 3.2 Steam Boiler Area 30
- 3.3 Production Areas 31
- 3.4 Compressor Room 31
- 3.5 Milk Factory 32

4.0 Summary of Results 33
- 4.1 Short-Term Energy Conservation Opportunities 33
- 4.2 Long-Term Energy Conservation Opportunities 41
- 4.3 USAID Equipment Specification For Selected ECO 42

5.0 Plant Management Organization/Recommendation 46

List of Tables

Table 1. ECO Summary 5
Table 2. Electric Motors 10
Table 4. Insulation Thickness for Steam Supply Line 37
Table 5. Steam Condensate 38
Table 6. Thermal Water Supply 39
Table 7. Thermal Water Return 40

List of Figures

Figure 1. Organization Chart 7
Figure 2. Sweets Plant Electric Distribution System 9
Figure 3. Boiler Steam Flow Diagram 12
Figure 4. Deareator, Water Conditioning and Preheater 14
Figure 5. Total Gas Consumption 16
Figure 6. Boiler Gas Consumption 17
Figure 7. Steam Production 18
Figure 8. Steam Use Breakdown 19
Figure 9. Boiler Efficiency 20
Figure 10. Electric Consumption 21
Figure 11. Electric Use Breakdown 24
Figure 12. Electric Demand 25
Figure 13. Hourly Electric Demand 7/21/89 26
Figure 14. Hourly Electric Demand 12/20/89 27
Figure 15. Hourly Electric Demand 12/10/91 28

List of Appendices

Appendix A
Combustion Analyzer Boiler Readings

Appendix B
Photographs

Appendix C
List of Abbreviations

I. Industrial Energy Efficiency Program

The countries of Eastern Europe face unprecedented changes both in their political and economic systems. To aid in the transition to market economies, the U.S. Agency for International Development (USAID) designed the Eastern Europe Emergency Energy Program. Resource Management Associates of Madison, Inc. (RMA) is the technical assistance contractor for the Industrial Energy Efficiency Component (IEEC) of the program in Lithuania.

The Industrial Energy Efficiency Component was designed to address the problems of industrial energy efficiency with a short-term program aimed at the immediate needs of industry. The program involves three main activities:

1. To identify and implement cost-effective low-cost/no-cost energy improvements, with an emphasis on oil savings.

2. To conduct energy audits and transfer energy auditing and management techniques, including financial and economic analysis.

3. To provide energy auditing and/or energy efficiency equipment to implement the program objectives, improve energy management, and identify additional energy efficiency opportunities.

The IEEC program deliverables consist of plant audit reports, a policy and institutional analysis report, and the in-country audits, training, and equipment delivery and installations. The tasks are being carried out by a team of energy specialists and policy analysis experts in four different phases:

- Phase One: Screening - During this phase the plants to be audited will be identified, and a specific plan to implement the following phases developed and put in place.

- Phase Two: Industrial Plant Energy Audit/Training - A team of energy specialists will arrive in-country and perform a detailed energy audit at the eight selected industrial sites. They will identify short-term energy efficiency measures, develop recommendations to implement these measures, demonstrate and train plant personnel on auditing techniques, and demonstrate financial and economic methodologies for justifying energy improvement projects. Additional equipment will be ordered for Phase Three.

- Phase Three: Implementation - The recommendations identified in Phase Two will be implemented, evaluated, and modified as necessary. Additional

training will be provided and the final energy efficiency equipment turned over to the host country.

Phase Four: Analysis of Factors - This phase will analyze the factors that make up energy efficiency management and investment decision making. Recommendations for policy reform and options for enhanced energy management will be identified and a program for implementation suggested.

Energy monitoring and testing equipment will be turned over to the Lithuania industrial sector and the Government of Lithuania (GOL). The GOL will be provided with analysis and recommendations for further energy efficiency measures.

ii. Executive Summary

This report describes the energy audit that was performed at the Vilnius Sweets plant. The audit was performed from December 9 - 13, 1991. A pre-audit visit was performed by the Energy Efficiency Component Team Leader to obtain preliminary facility information. The Vilnius Sweets plant produces candy that is sold in many stores around Lithuania. In the last year it has only been able to produce at 50% of normal capacity due to raw material shortages. Another important service it provides is to make and supply steam to a milk factory, a bakery, and residential housing.

The majority of the electric consumption is due to motors with the 125 kW ammonia chiller as the largest. Annual electric consumption is about 3000 MWh. The peak demand is between 1200 kW and 1600 kW which results in a load factor of about 30% for the year. At the time of the audit electricity cost was .051 R/kWh ($ 0.0007/kWh) and had a demand charge of 10 R/peak monthly kW ($ 0.143/kW). This gives an everage electric charge of .084 R/kWh ($.0012/kWh).

The steam produced by the facility in its three boilers consumes about 99% of the total gas consumption for the facility. Monthly gas consumption is about 700,000 m^3. The boilers are rated at 15 ton/hour and deliver steam at about 12 bars to the facility and other users. The Sweets facility uses about 25% of the steam produced with 64% of steam produced sold to the Milk and Bakery facilities. Boiler combustion controls are based on a linear dependence of air to fuel that is established once every three years. The steam and gas metering were found to be inaccurate during the audit. At the time of the audit, natural gas cost 1.054 R/m3 ($.00043/ft3) and steam was sold at 51.9 R/Gcal ($0.19/MMBTU).

The energy costs for gas and electricity have increased drastically in the last year and are scheduled to take another significant jump in the beginning of 1992. Because of the extreme volatility of the energy prices and because world energy prices are the most likely outcome, world energy prices were used in the economic analysis of energy conservation opportunities (ECO).

The main focus of the audit was on the boilers due to their high energy use. Combustion analysis measurements were taken on all three boilers. During the testing, the efficiency of one boiler was raised by 4.7% using the combustion analyzer measurement of oxygen and reducing the amount of excess air. The production areas were investigated and it was found that the chilled water was circulated through the piping when no cooling was needed.

The main short-term ECO recommended for the plant is to increase the level of accurate metering for the boilers. This includes using more accurate meters and pressure transducers to measure steam and gas flows, and to add oxygen sensors in each boiler stack to monitor excess air levels. It is estimated that with this improved instrumentation, the boiler efficiency can be improved by an average of 9%. This would result in a savings of 1.0

million m^3 per year in gas savings or a cost savings of $105,000. The estimated cost of the measure is $23,000, which would result in a payback of 3 months (see *Table 1*).

The other short-term measures that are recommended include the pipe insulation and cooling water recovery. Insulating thermal water, steam, and condensate pipes has a payback less than 1.6 years. The installation of a system to recover process cooling water for use as make-up water in the boiler should result in less than a one year payback depending on the local cost of the project.

The long-term projects recommended are: the use of automatic controls to maximize combustion control; the installation of an energy management control system to control demand and thermal loads; and the increased control of the chillers to reduce head pressures for energy savings in cooler weather. Other long-term opportunities follow.

A significant percentage of condensate is not recovered. Returning condensate will increase the overall system efficiency and reduce operating costs in two ways. Energy and therefore money will be saved by minimizing the amount of make up water heating. Money will be saved through reduced energy consumption and by reducing the amount of chemicals needed for make up water treatment. The areas with the greatest potential for energy savings are the sweets plant and the milk plant.

Western type time of use rates or demand charges are not used. The government of Lithuania should consider implementing time of use rates or demand charges for electric consumption. Higher electric rates at coincident or non-coincident peaks will provide the market with pricing signals to encourage conservation, minimize new plant construction, and make more efficient use of existing resources.

Air is leaking into the exhaust stacks of the boiler. This reduces the efficiency and effectiveness of the waste heat recovery economizer. Sealing the air leaks will save energy and increase the system's efficiency.

The milk factory's steam use is not metered. Also, the steam is reduced from 13 to .7 bars with a significant loss of energy. Providing meters to monitor steam consumption and establishing a billing system where charges are based on the net energy consumed would give the milk plant an economic incentive to recover the now wasted condensate.

The equipment recommended for purchase and implementation by USAID for the facility would provide the increased efficiency and energy savings for the boilers. The specified equipment includes sensors of stack emissions for all three boilers, pressure compensated steam meters for the boilers and the two main steam users, a gas meter for the boilers, and a microprocessor and recording device(s) that allow proper monitoring of the system for efficiency improvements.

Table 1. ECO Summary

SHORT-TERM ECO'S (Recommended for funding through USAID)

ECO	Energy Savings (Gcal)	Cost ($)	Savings ($)	Simple Payback (months)
Boiler Combustion Control Metering	8000	23,000	105,000	2.6
Pipe Insulation*	-	-	-	6-18
Cooling Water Recovery*	_	6,000	6,933	10.3

LONG-TERM ECO'S (Recommended by the audit team but not funded by USAID)

Automatic Boiler Combustion Control

Energy Management System

Improve Chiller Controls

Condensate Recovery

Seal Exhaust Stacks

Milk Factory Steam and Condensate Metering

* Short-term ECO's recommended by the auditors but not funded by USAID.

1.0 Plant Description

The Vilnius Sweets Factory produces candy for general consumption in Lithuania. At present, most of their sales is within the old Soviet system. The capacity of the plant is 24,000 tons of candy per year. Their production currently is at 50 to 60% of their overall capacity due to a shortage of raw materials. Presently the plant is operating from 8:00 am to 11:30 pm five days per week. They have about 800 employees.

They are located close to the heart of Vilnius and are situated next to the 'Vilnius' Milk plant. Because of this proximity to the Milk plant, the Sweets plant provides steam from their boilers to the Milk plant, which operates every hour all week long. The Milk plant is the only milk plant in Vilnius and because it provides a staple for the general population it is given some priority by the government in its allocation of resources such as energy. This can have some benefit to the Sweets factory because they are the provider of this steam energy and require the gas energy to accomplish this vital service.

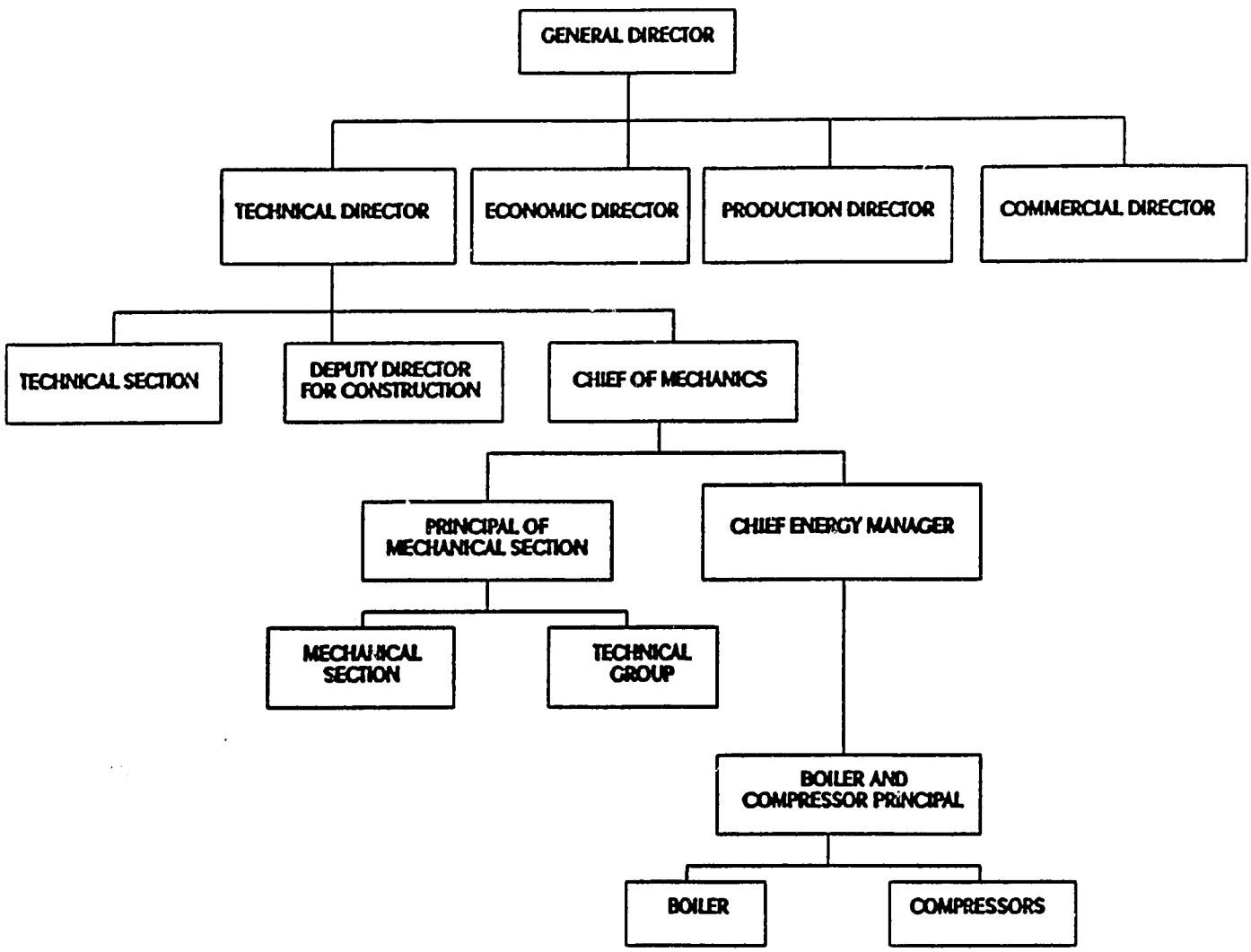
1.1 General Energy Utilization

The Sweets plant has an electric demand of about 1500 kW at full production capacity. The electric equipment includes large refrigeration compressors, circulation pumps, large motors used for mixing and rolling, and many smaller motors for process, ventilation and material conveyance. Their power factor is generally acceptable due to automatic condensers installed. The cost of the electricity purchased based on the first eight months in 1991 has been .94% of their production costs. This is two times the percentage they were paying in 1990 and three times the percentage they were paying just two years ago in 1989. Their cost for gas consumption has risen from 1.1% of production costs in 1989 to 3.1% in 1991.

1.2 Organization

The general organization of the plant is shown in *Figure 1*. There are four directors that report to the general director. They head the technical, economic, production and commercial departments. The figure only shows the sections that relate to decisions on energy projects. These sections are under the direction of the Technical Director, Mr. Algirdas Joudkazis. The primary sections under the Technical Department are the Technical, Construction and Mechanics sections. The Mechanics section is where the energy manager is placed. The chief energy manager, Mr. Alfredas Samerdokas, is responsible for the operation of the boiler and the refrigeration compressors. The other subsection is responsible for mechanical systems such as the electric system and motors. The chief engineer for this section is Mr. Edvardas Azlauskas.

Figure 1. Organization Chart

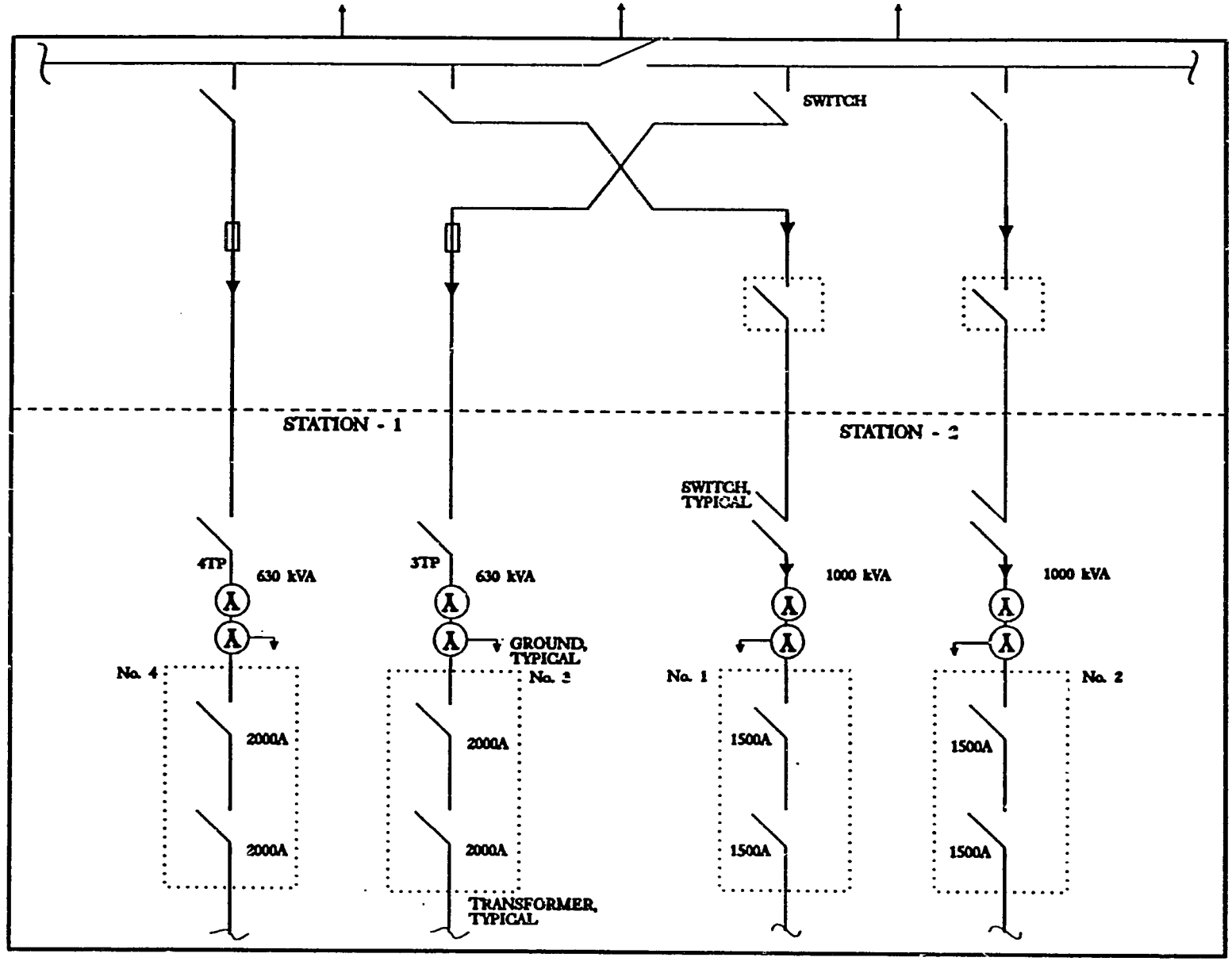


ORGANIZATION CHART

1.3 Electrical System

The electric distribution system uses four transformers with two interconnected systems as seen in *Figure 2*. One of the systems uses two transformers that are 630 kVA and the other system uses two 1000 kVA transformers. There is a demand meter that measures the power for each system, but not for the overall power consumed. The final demand for the entire plant is based on adding together the highest demand for the month for each system and multiplying this sum by .98 in an attempt to correct for diversity of the two systems. From data reviewed at the facility, it appears that this correction factor is too high. *Table 2* lists the main electric motors used in the factory.

The largest motors are on the ammonia refrigeration compressors, but they do not operate simultaneously. Only about one compressor is required during the winter and two compressors are used in the summer. Three of the rollers are used about 16 hours per day, while the others are used for about one shift. The operation of the other motors generally depends on the production rate and schedule.



ELECTRICAL DISTRIBUTION DIAGRAM

Figure 2. Sweets Plant Electric Distribution System

Table 2. Electric Motors

Power (kW)	Number	Area	End-Use
125	6	Compressors	NH4 Refiger.
75	4	Preparation	Rollers
55	6	Preparation	Rollers
55	3	Boiler	Circ. Pumps
40	6	Preparation	Melters
40	2	Boiler	Pumps
30	2	Preparation	Collectors
30	2	Cooling Twr.	Fans
30	1	Boiler	Stack Fan
30	4	Compressors	Brine Pumps
30	4	General	Elevators
20	2	Boiler	Pumps
20	3		Fans
20	2	Compressors	Air Comp.
20	3	Preparation	Sugar Melt.
20	2		Vacuum Pumps
20	2	Sweets Sect.	Mixing
20	4		Fans
7.5 - 15	25	General	General
3.0 - 5.5	220	General	General
.27 - 2.2	470	General	General

1.4 Thermal System

Process steam is produced by the plant itself for distribution to a small district steam distribution system and a thermal water district heating system. Steam is used on-site in the process of making sweets. Steam usage by the Sweets factory is approximately 25 to 35 percent of the boiler output depending on the level of space heating requirements. Steam is exported to a Packaging plant, Milk processing plant and Bakery located close to the plant. Details of the steam production and consumption is as follows:

Boilers: Three Russian-made boilers, installed in 1968, supply steam to a common header for distribution:

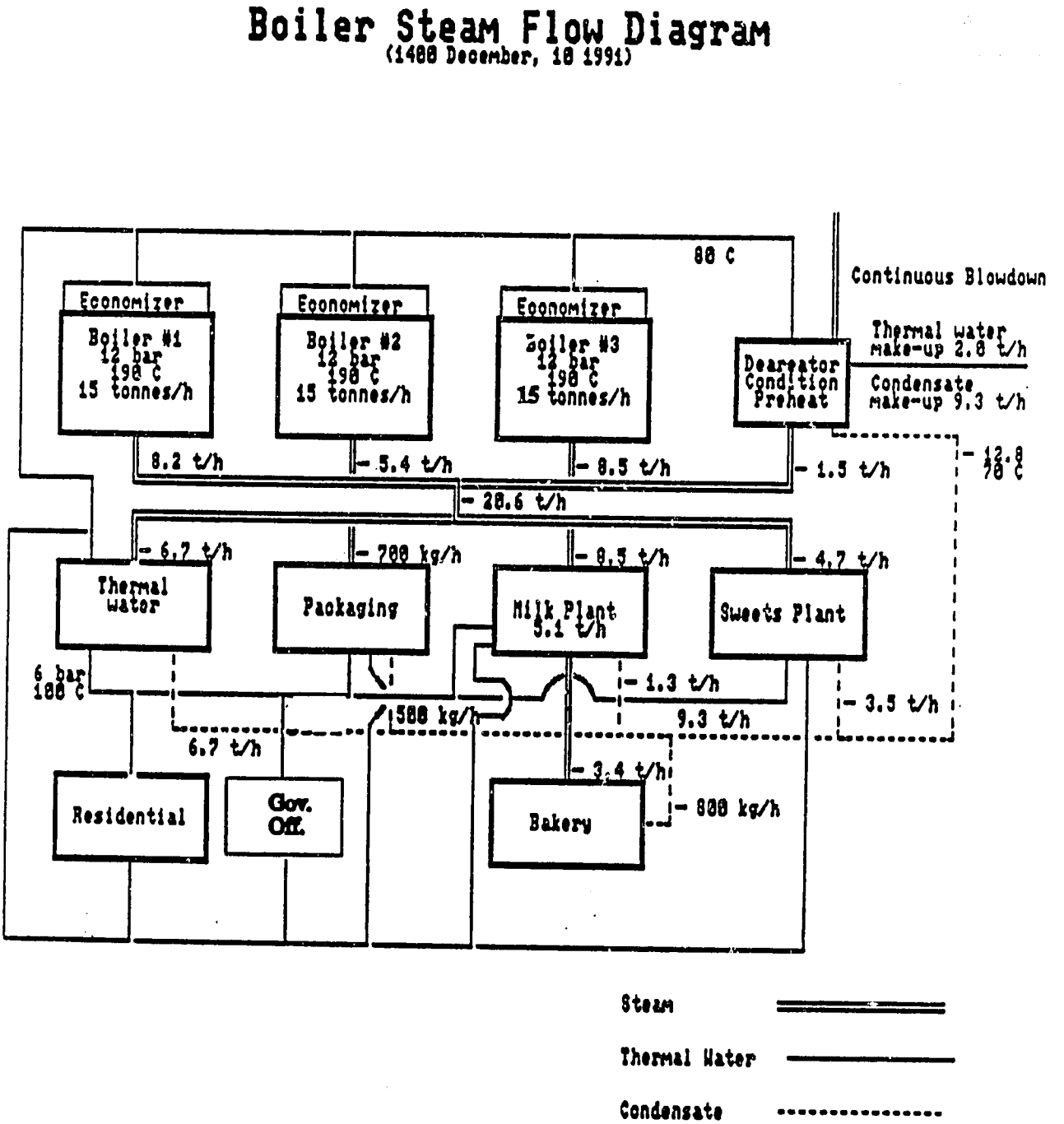
Capacity:	45 metric tons/hour (15 each)
Pressure:	12 bar saturated steam
Temperature:	191° C
Fuel:	Pipeline natural gas from the Soviet Union, but can be fired on oil
Operations:	2 on-line, one standby
Type:	Water tube with economizer, no combustion air preheater(other than drawing combustion air from inside the boiler house)
Controls:	Manual or automatic control of air/fuel based on measurements of stack gases once every three years, there is no continual stack gas monitoring
Instrumentation:	Pressure, temperature, water level and steam flow

Two boilers are usually operated during the day and one at night in the summer. In the winter three boilers are sometimes required during the day and two are usually on during the night.

The control of the boilers is accomplished by maintaining the steam drum pressure by increasing fuel and air. The ratio of fuel to air is regulated manually or automatically. Once every three years the automatic controls are set to maintain a linear relation between air pressure and gas pressure. The control sends a signal to the air dampers based on the steam requirements. As the air pressure is changed, the gas valve is adjusted to maintain the gas pressure linearly to the air pressure.

Steam is distributed to the plant, and exported, via a header operating at 10 to 12 bar. A schematic of the steam system is presented in *Figure 3*. Thermal water is used for process and space heating requirements in the Sweets factory. Thermal water is also exported to two small government office users, the packaging plant and residential users.

Figure 3. Boiler Steam Flow Diagram



Steam metering exists only for steam sent to the Sweets plant and the Milk plant who then sends steam on to the Bakery. No metering exists for the thermal water used by the plant or billed to the customers. Steam and thermal water billing is done (and accepted by the customers) using estimates calculated by the Sweets factory staff.

Each boiler has a steam flow meter. Data from these 3 meters and the steam meters to the Sweets and Milk plants were used, along with estimates of other users, for the steam balance data shown in *Figure 3*. These data were taken at 1400 hours on December 10. Natural gas consumption was also measured at this same time at a value of 1180 Nm^3/hour to the entire sweets plant. The energy of the steam produced exceeded the incoming energy of the natural gas. This indicates a serious problem in the accuracy of the existing meters and shows the inaccuracy in estimating bills for the other customers.

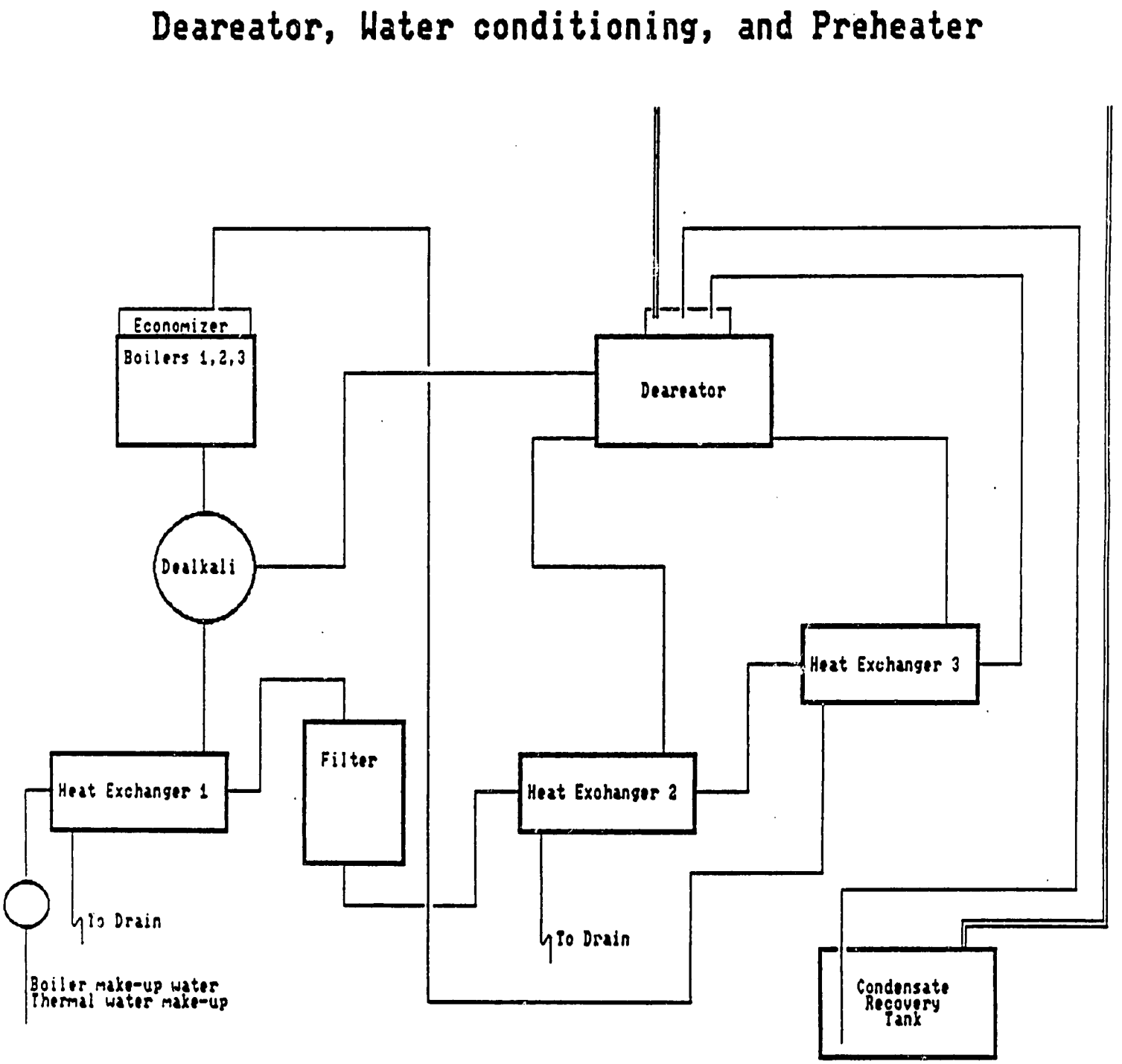
Condensate is recovered from the sweets manufacturing plant and from all other steam customers. Condensate recovery is estimated at 75 percent from the sweets plant, 100 percent from the thermal water heat exchangers (they are located in the boiler house adjacent to the boilers) and 25 percent from other customers. Return condensate and some blowdown steam are used to preheat make-up water and total boiler feed water. A schematic of the water conditioning and preheating system is shown in *Figure 4*. Thermal water and condensate return water is taken from the city water supply and has a separate, single meter. The meter reading approximately concurred with the estimated make-up water flow rate shown in *Figure 3*.

1.5 Process Description

The present production is under fifty percent of production capacity due to the lack of raw materials such as cocoa beans. The main process areas of the plant include preparation, glazing, cocoa candy, caramel boiling, wafer production, popcorn, a syrup boiler and a caramel hard cover section. The preparation section has two driers for producing cocoa powder and two driers for nuts. The driers are heated by steam. Large electric motors in the area include motors for the vibrating separation machine and the cutter. A chocolate glazing is applied in the glazing section. There are five large roller mills with 55 kW motors and a press for cocoa butter. In the cocoa candy section there is a need for cooling water at -10 °C for the process.

In the caramel boiling section the syrup that has been prepared is collected. There are rollers for berries that are preheated by steam to 120 °C. In the boiler area the syrup that is used in the caramel candy is mixed and heated using six bar steam. The wafers are toasted in gas ovens, one of the few places that uses gas other than the main steam boilers. The popcorn area was not in production due to the lack of corn. The caramel hard cover area required storage of the candy for twenty four hours to allow the candy to cool and harden.

Figure 4. Deareator, Water Conditioning and Preheater



2.0 Plant Energy Profile

As mentioned earlier, the plant produces steam for its own use and for other steam users. These other steam users are the Vilnius milk plant, a bakery, a packaging plant and the district water heating system for residential heating in the area. The plant usually uses natural gas supplied by Russia. The last time they used Mazute (Oil #6) was during repairs on gas lines four years ago. Therefore, they do have the equipment to burn oil to produce steam if necessary.

2.1 Gas Consumption and Steam Production

The total consumption of gas is shown in *Figure 5* for 1989 and 1991. In the year 1989, there was a greater production of candy than in 1991. Therefore, the consumption of gas for 1989 is much higher than in 1991. During 1989 it appears that they reduced production during the summer. In 1991 the consumption of gas varied from a high of about .95 million m^3 to a low of .75 million m^3 with an average of about 0.7 million cubic meters per month.

Figure 6 shows boiler gas consumption for the years 1989 and 1991. The boiler gas consumption is about 99% of the gas consumed by this facility with the other 1% used in the wafer toasters. Therefore, *Figure 6* is almost identical to *Figure 5*. The accuracy of the gas consumption metering is uncertain. During the audit it was discovered that the facility staff regularly increases the metered gas consumption by 5 to 6%. For example a reading for one day was reviewed and it was found that the staff increased the consumption by 20% over the gas meter strip chart recordings. Their reason for doing this was to pay for more gas this year so that next year their allocation of gas, based on this year's use, would be higher. Because they are at only 50% production capacity, they wanted to have more gas available next year if they are able to acquire the raw materials to increase production.

The curves for steam production for the years 1989 and 1991 shown in *Figure 7* are very similar to the curves for the gas consumption, which is no surprise since most of the gas is used to produce steam. Again, steam production and use is down for 1991 due to the reduced production. *Figure 8* shows the steam use breakdown. Most of the steam (64%) is used by the diary and bakery with the sweets plant using only one quarter of the steam they produce. *Figure 9* plots the efficiency of the boiler based on the gas consumption, the lower heating value for gas given in their contract, and their monthly steam production. It is interesting to note some unrealistic values that occur for 1989 (94 and 98% efficiency). This points out again the need for more accurate metering of gas and steam.

2.2 Electric Consumption

The electric consumption for the Sweets plant is shown in *Figure 10* for 1989 and 1991. The curve for 1989 is similar in shape to the gas consumption curve as electricity consumption is also dependant on production. The electric consumption for 1991 is not as constant

Figure 5. Total Gas Consumption

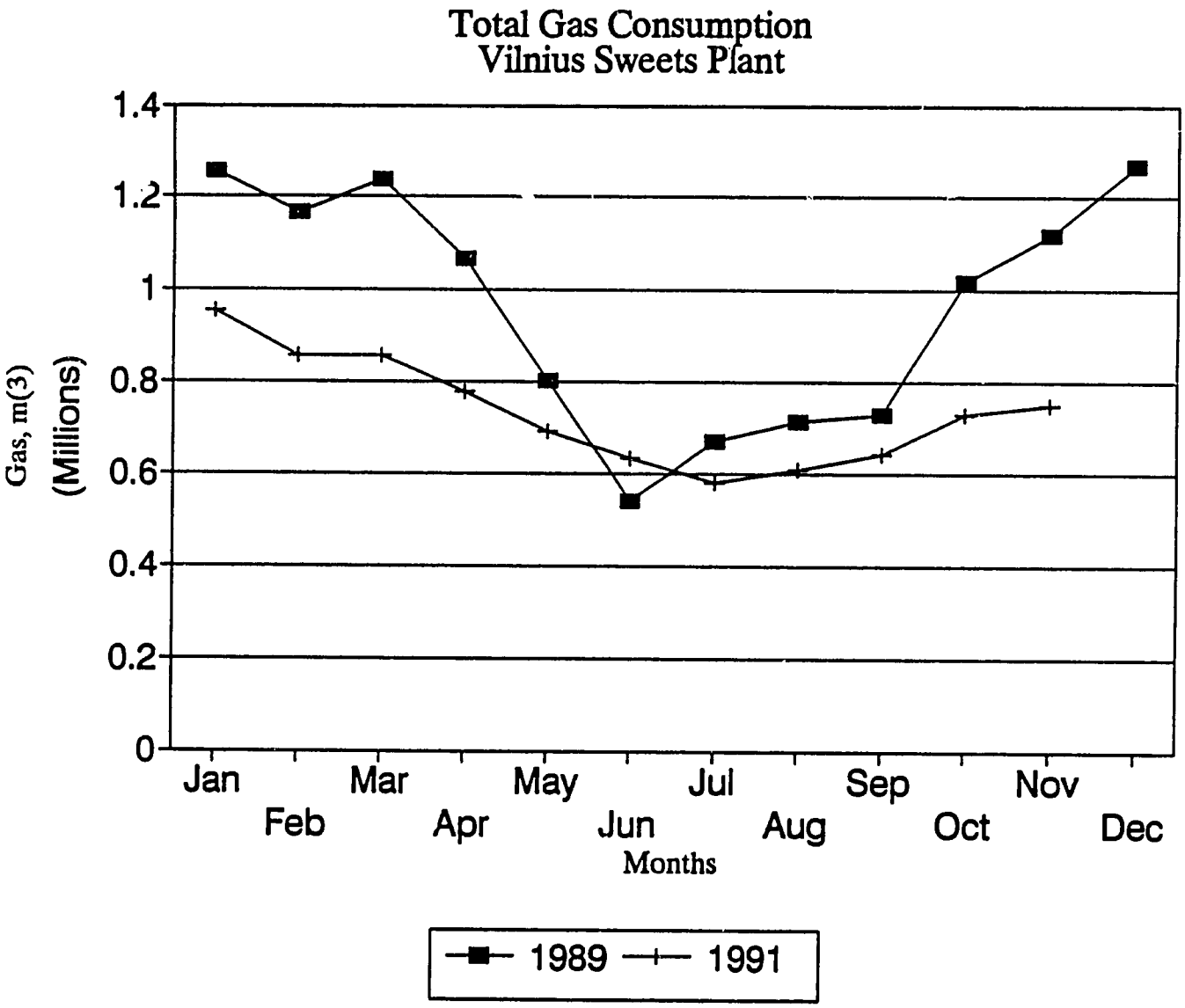


Figure 6. Boiler Gas Consumption

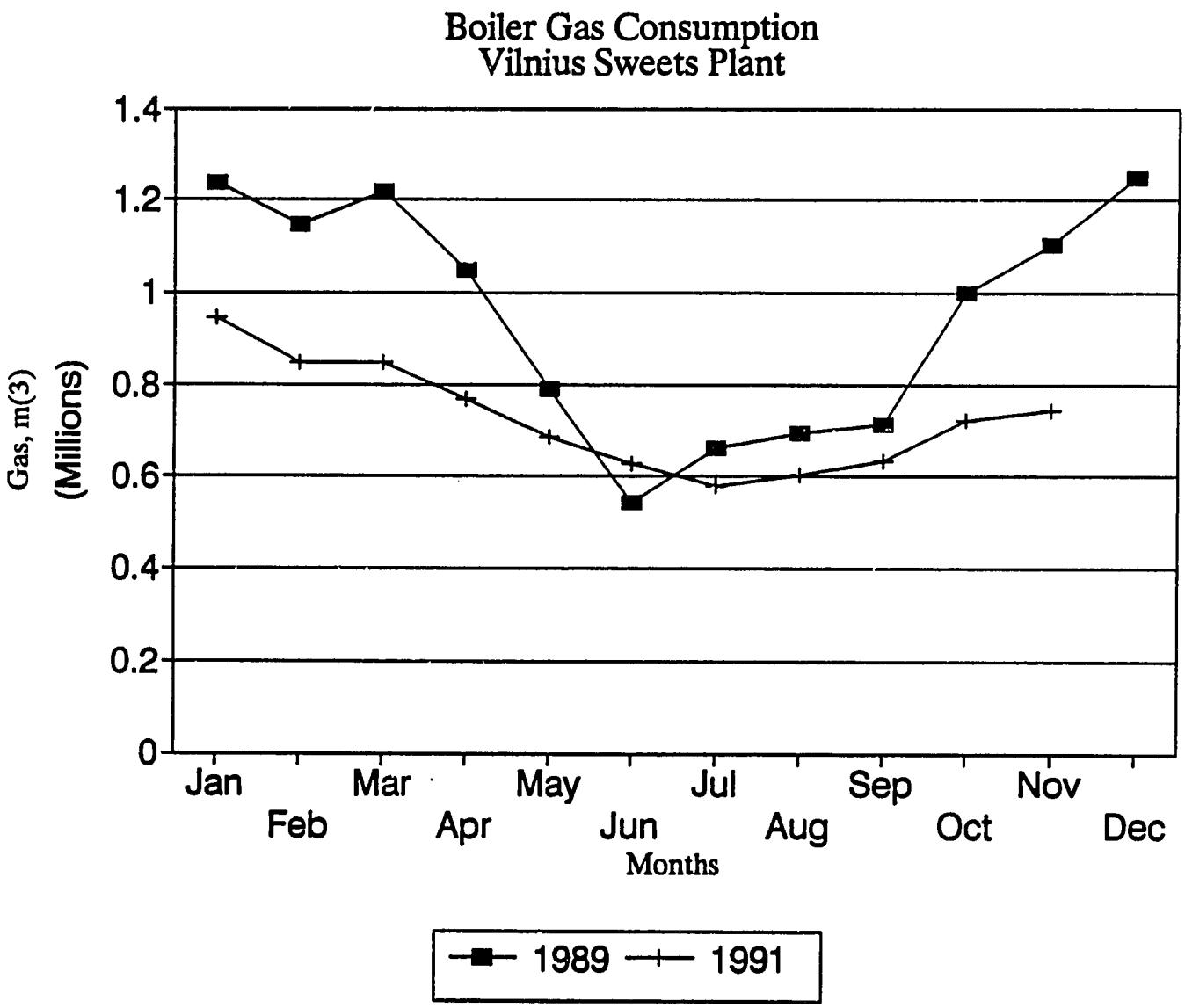


Figure 7. Steam Production

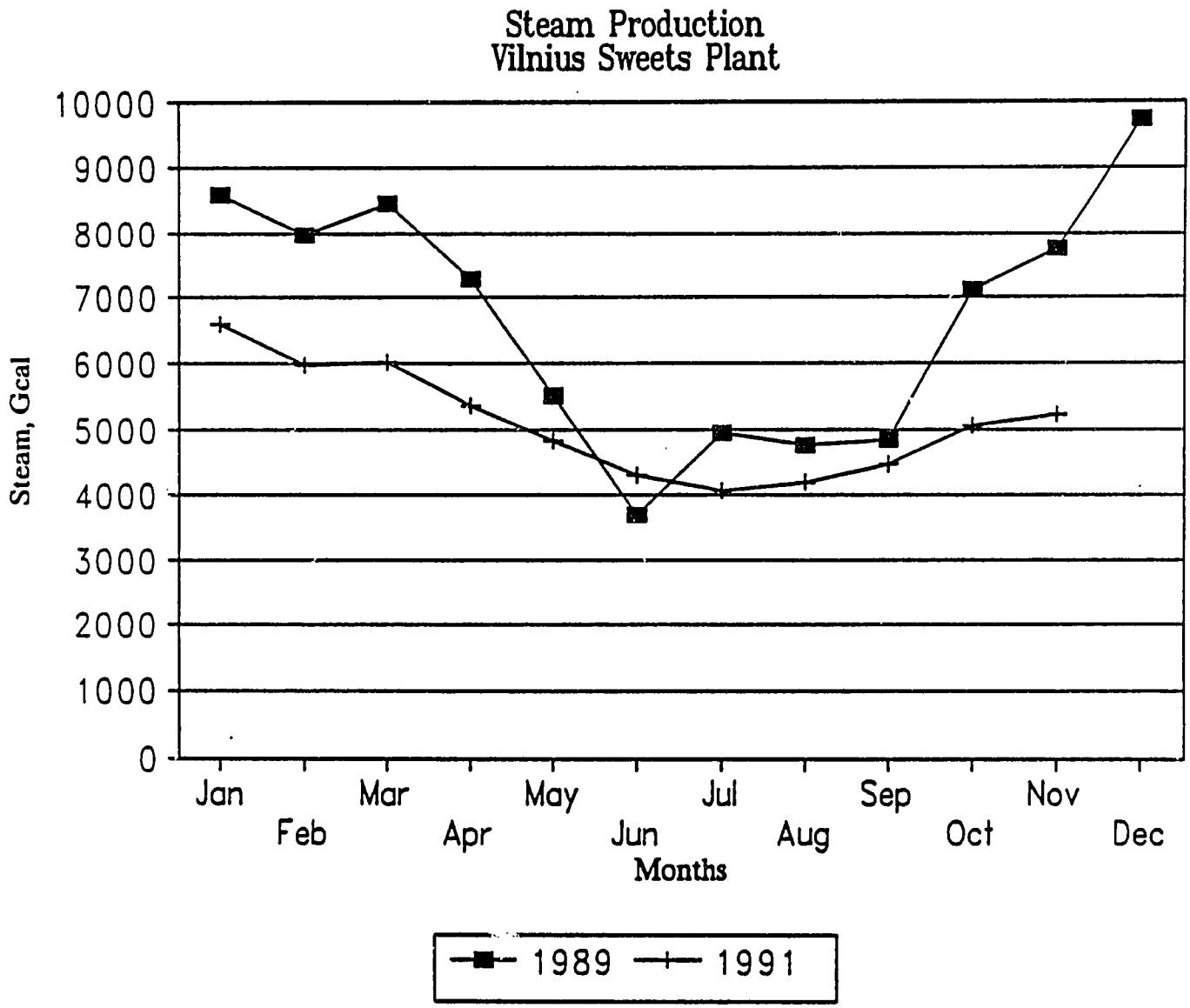


Figure 8. Steam Use Breakdown

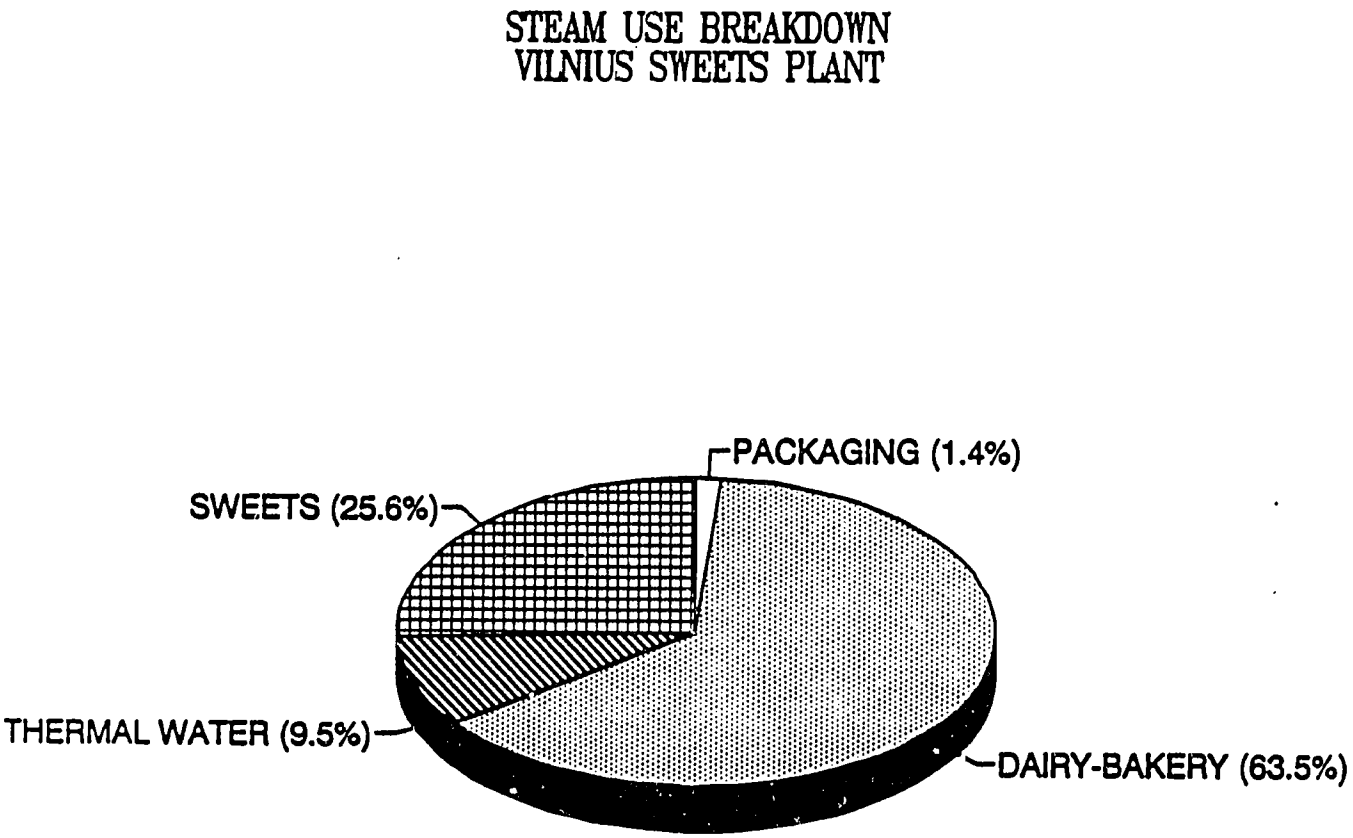


Figure 9. Boiler Efficiency

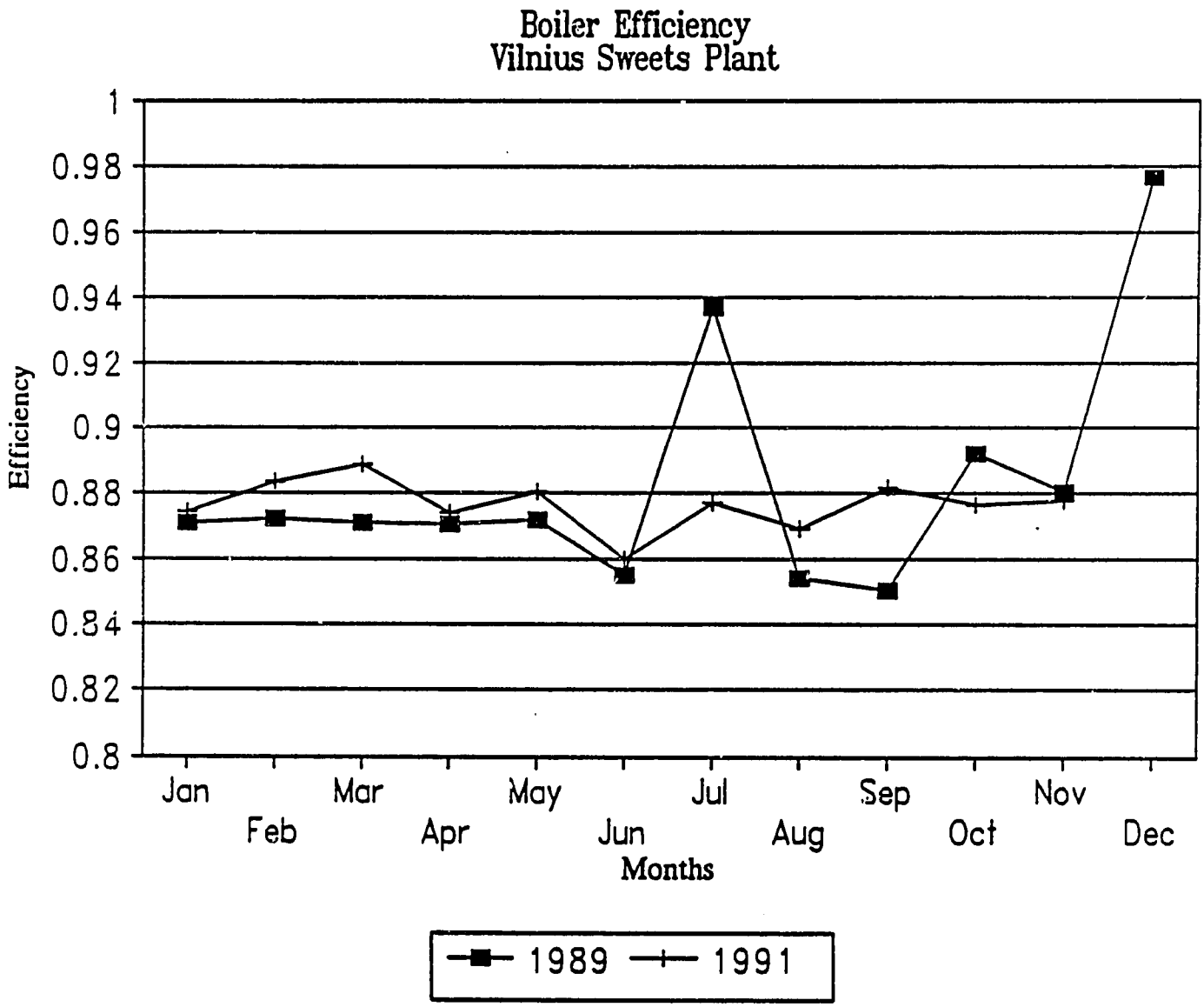
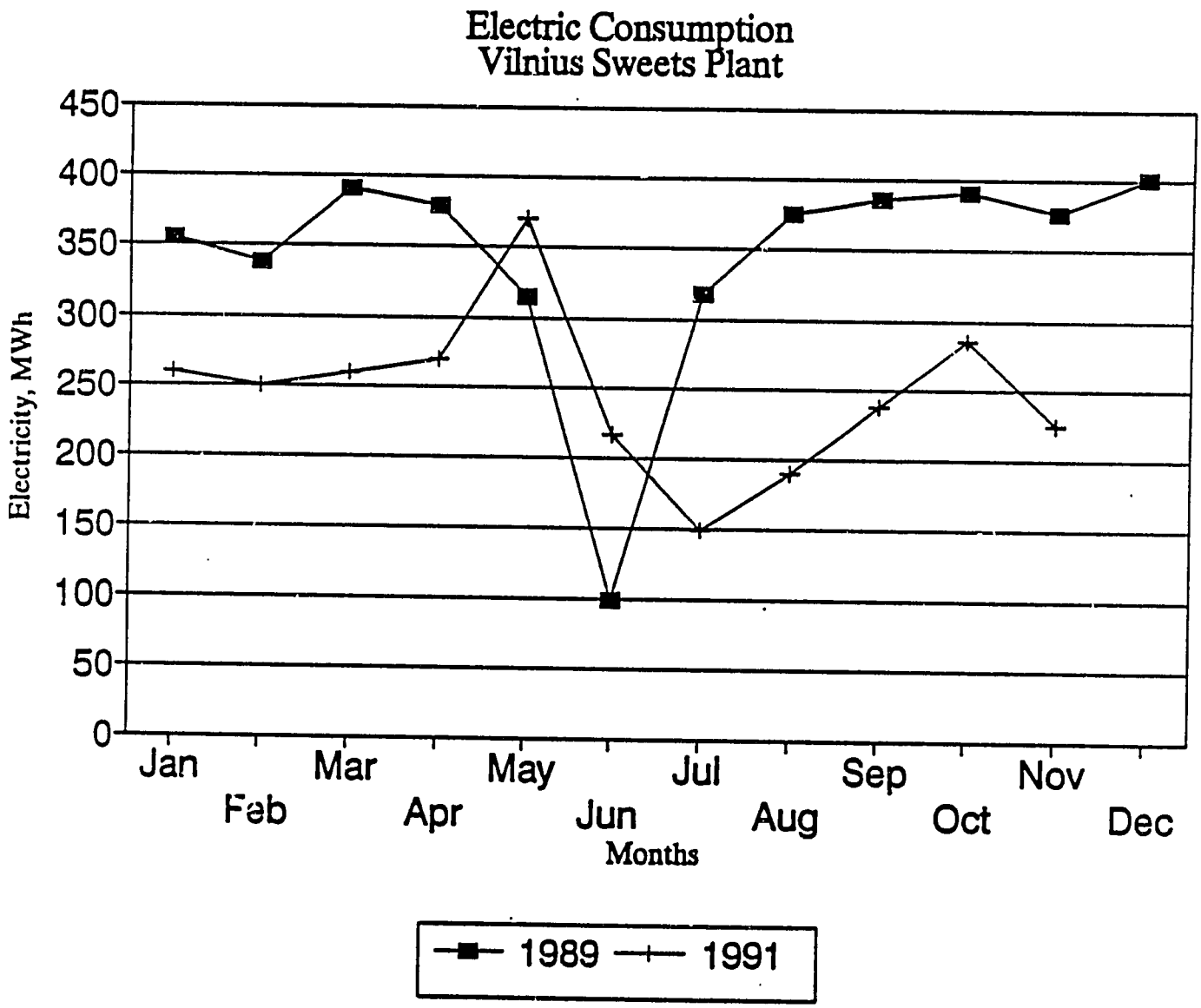


Figure 10. Electric Consumption



throughout the year because this consumption is tied only to the Sweets plant and its production, while the gas consumption is very dependant on the production of the milk and bakery plant which is more constant.

Figure 11 shows the electric use breakdown for the Sweets plant. The largest user of electricity is process motors at 80% with ventilation using about 12%. This type of breakdown is typical of many industrial process facilities.

The monthly electric demand for the plant is plotted in *Figure 12*. Except for June of 1989, the demand is fairly constant for both 1989 and 1991. Of course, the average demand for 1989 is higher than 1991. The plant does not pay for their actual demand, though. They are required to estimate their demand for each quarter and are billed on this amount as long as they do not go over. If they do go over their estimate, they pay a penalty. Because the demand is relatively constant from month to month, their estimates are usually close to the actual demand.

Twice each year the plant tracks the demand of the facility on an hourly basis. *Figures 13 and 14* show this tracking for summer and winter, respectfully. It is of particular interest that the peak kW during the day is for only 3 to 4 hours. This is a very sharp demand curve and is not typical of most industries. The peak also falls exactly in the morning "on-peak" period, hours 9 to 11. This occurrence seems to be due to the need to establish the peak in order to secure the allocation of power for next year, such as with the gas consumption. *Figure 15* also indicates that the profiles have an artificial peak. This figure plots data for demand readings taken on one of the days during the audit. Because it was not an official day for demand readings, the profile is much flatter and lower than for the other days in 1989, and closer to what would be expected.

The use of demand projections for the bill and the concern over allocations of power for the next year reduces the ability to effectively use demand controls. Certainly if actual demand was billed, the peak demand of the profiles shown for 1989 could be reduced 200 to 400 kW.

2.3 Energy Costs

The energy costs for the plant have increased enormously in the last year. Gas prices have increased recently from .072 R/m^3 to the current price of 1.054 R/m^3, an increase of 1360%. They are presently selling steam for 51.9 R/Gcal and the cost to produce the steam was 25 R/Gcal at .072 R/m^3. The higher gas costs will place the facility in a difficult economic position when trying to recapture these costs in the selling of steam. The cost of the gas for using over their "allocated" amount A (or demand charge) for the month is five times the original cost for the gas. Their make-up water charge is 4 R/m^3, with 1.7 R/m^3 for water and 2.3 R/m^3 for sewer. The amount of make-up water per month is around 7500 m^3.

They are required to call each day to the gas dispatcher's office to give them an estimate of their gas requirements for that day. During very cold weather they are required to call every two hours with their estimates. Because of the low turndown abilities of the gas meter, they pay a minimum charge of 30% of their maximum gas consumption for each hour even if no gas is used. They do change the orifice plate between winter and summer to adjust for the lower gas consumption in the summer. When there is a gas shortage, the priority of actions is to first reduce the thermal water temperature to the residents, second reduce steam to milk and bakery plants, and third to reduce the steam to the sweets plant.

The electric costs are presently 0.051 R/kWh with a demand charge of 10 R/kW each month. With the demand charge included, the average electric cost for 1991 was 0.084 R/kWh. They have no direct penalty for power factor, but pay 0.02 R/kVAr. Because they have sufficient capacitors they do not have any kVAr costs. In the past, they would pay part of their bill as a barter in candy. Now they do not have any bartering on the bill.

2.4 History of Energy Efficiency Measures

Energy conservation measures have been very limited during the life of the plant as is true in the other facilities visited. Some of the measures that have been adopted include the automation of the air compressors and increasing production by reducing the breaking of cartons during production. Other measures that were mentioned by the staff include replacing motors with a smaller sized motor. Due to the dependence of energy consumption on load that would remain constant, this type of measure does not typically result in significant energy reduction.

Figure 11. Electric Use Breakdown

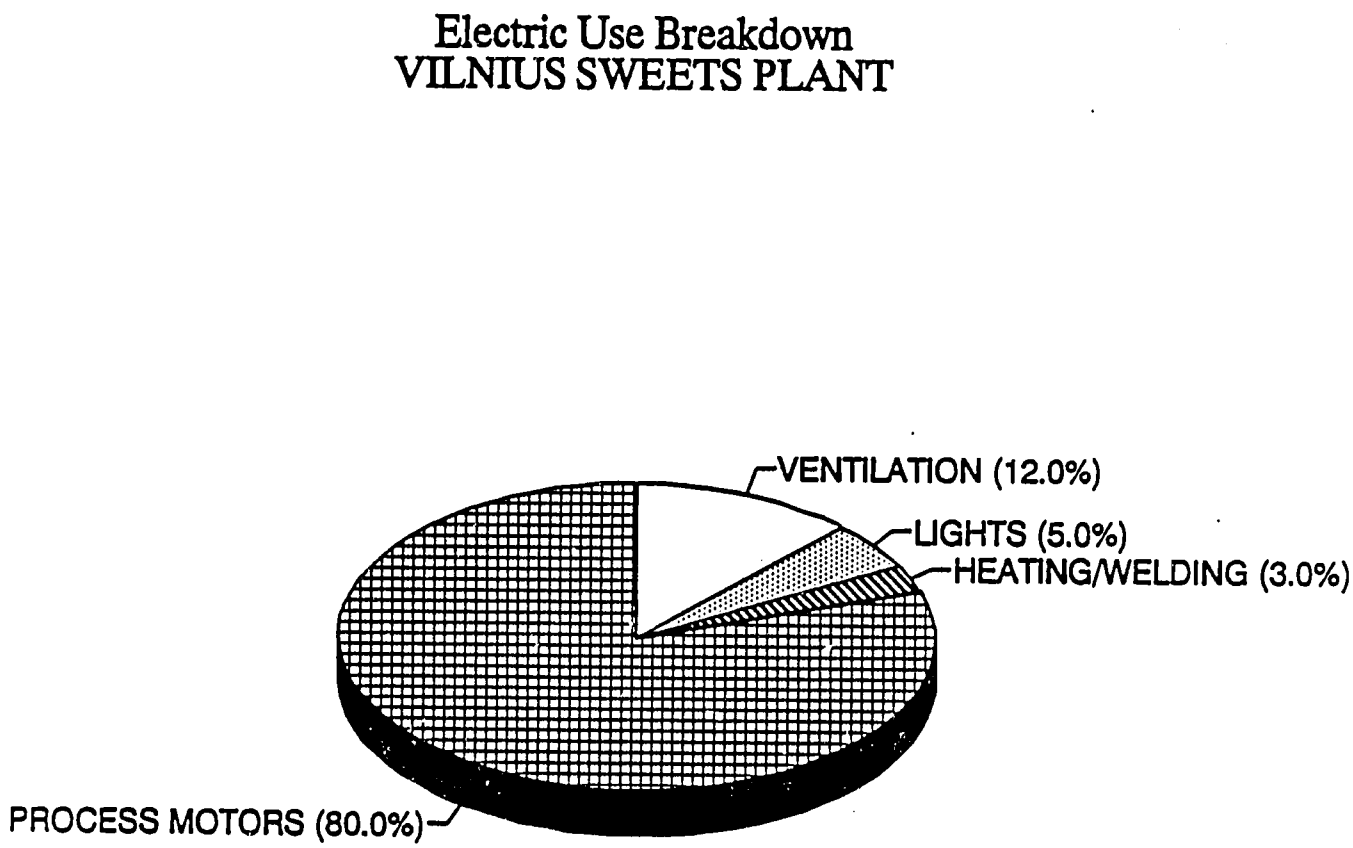


Figure 12. Electric Demand

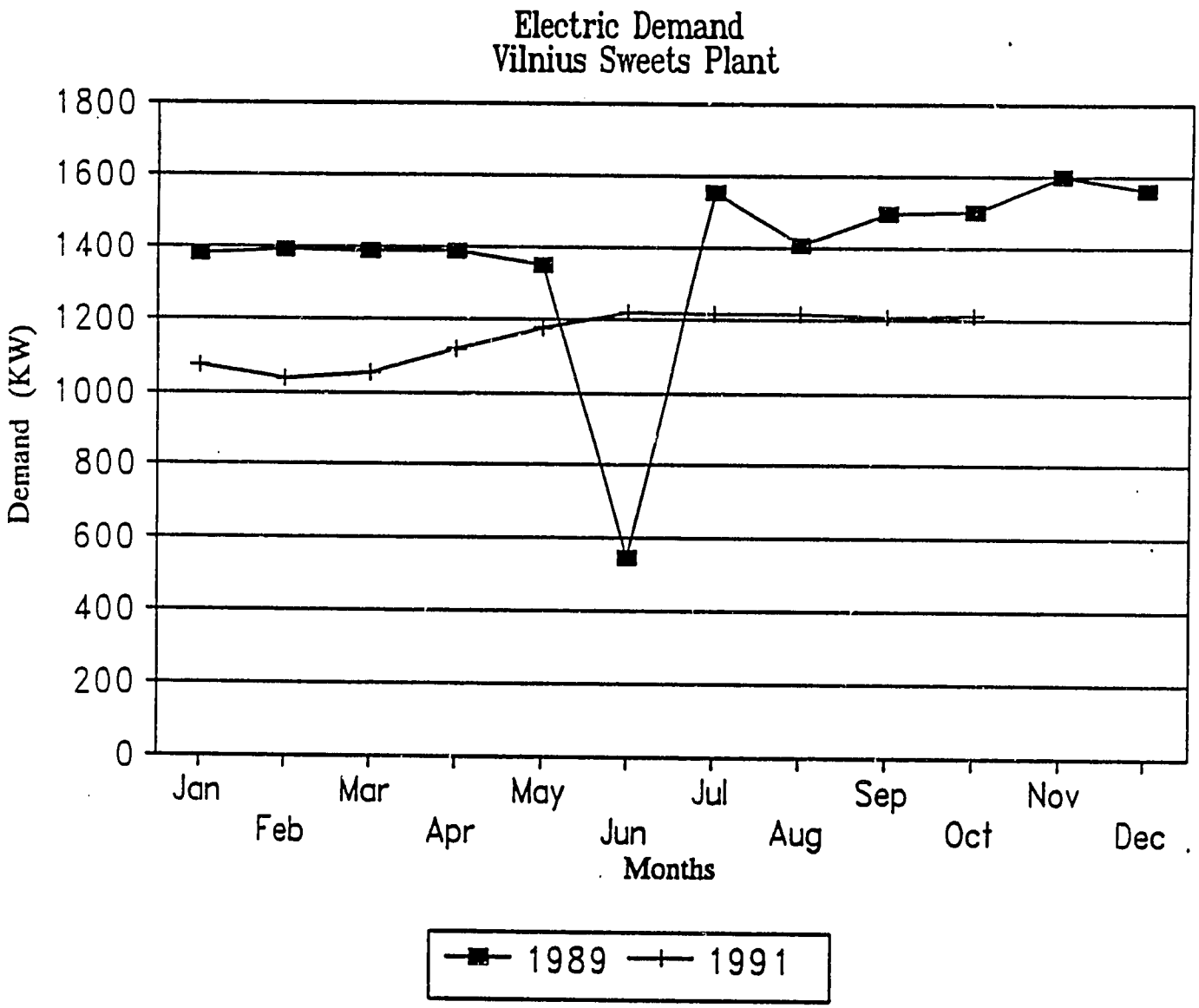


Figure 13. Hourly Electric Demand
7/21/89

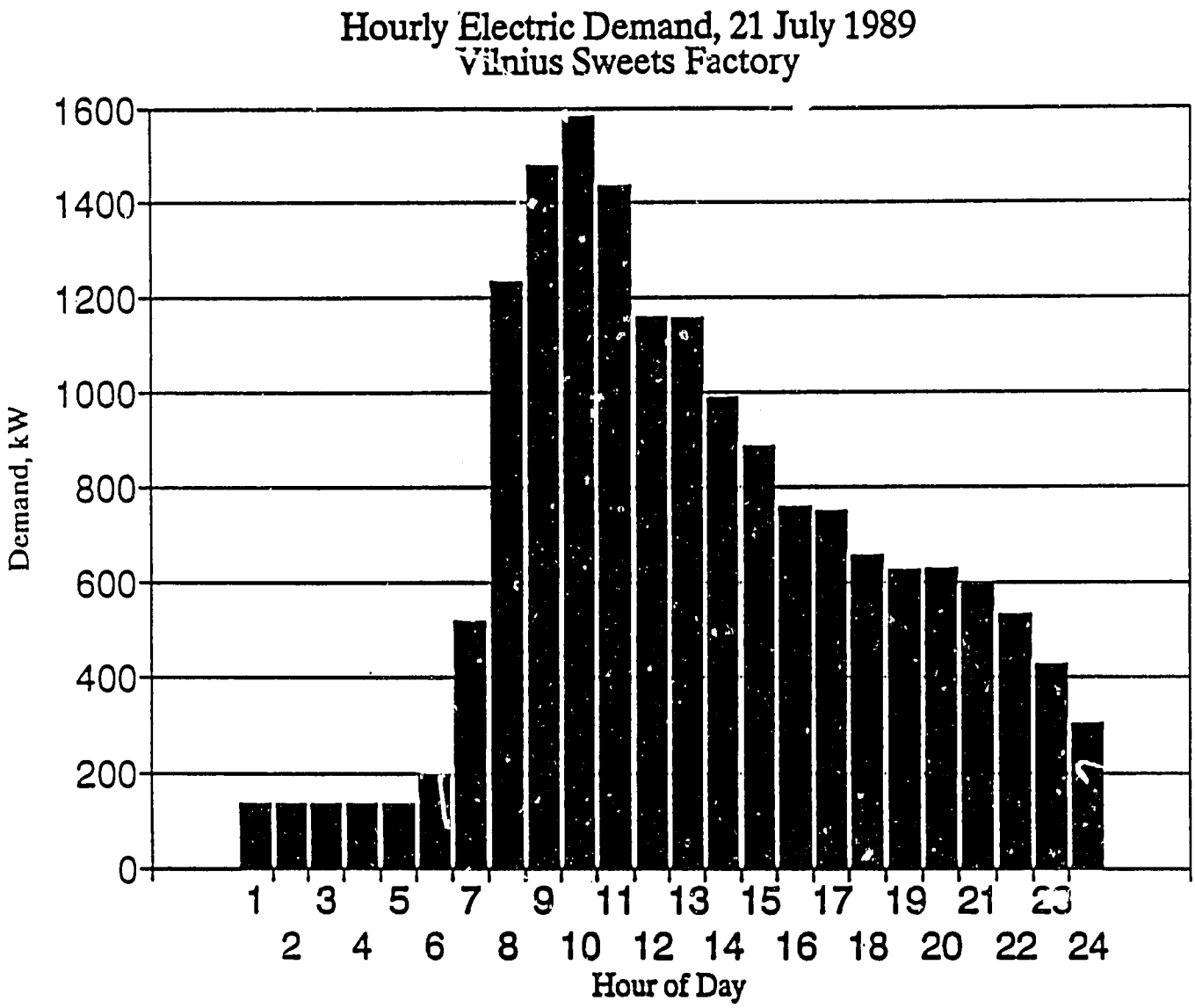


Figure 14. Hourly Electric Demand
12/20/89

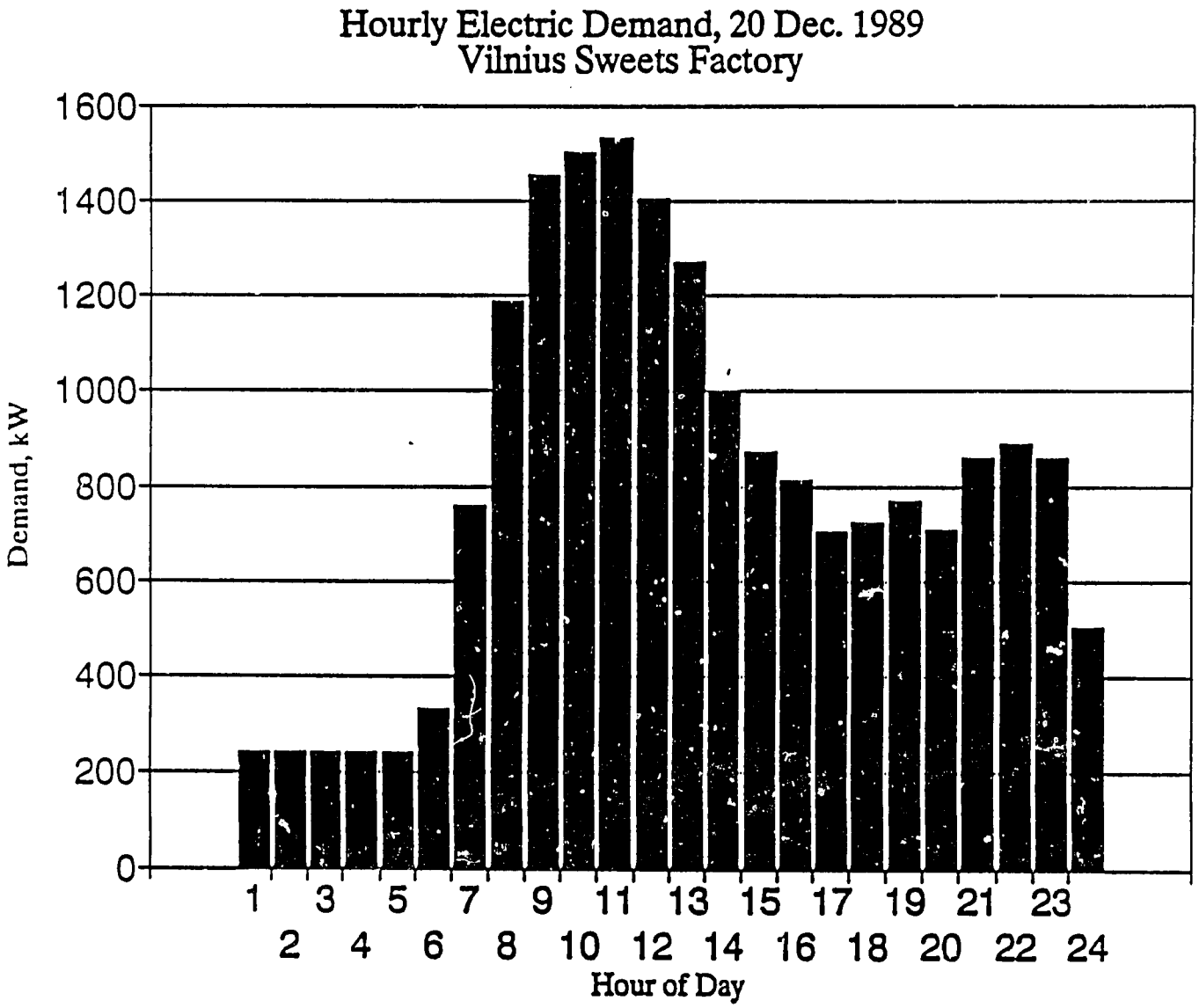
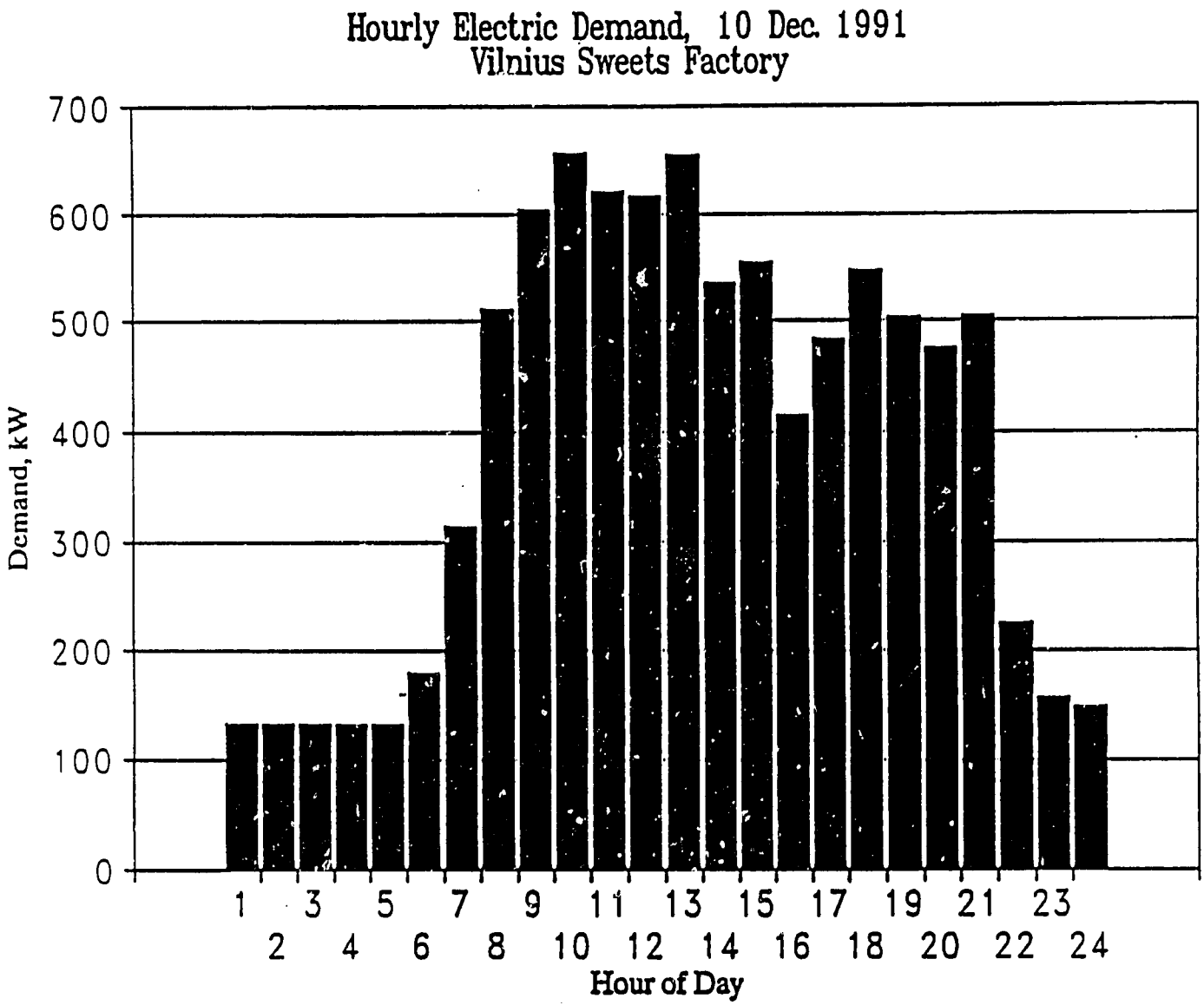


Figure 15. Hourly Electric Demand 12/10/91



3.0 Energy Audit Description

The audit was conducted over a five day period from December 9 to December 13, 1991. A pre-audit trip was made to the facility in late November by the Energy Efficiency Component Team Leader. Discussions were held with key personnel to determine the major energy issues, to describe the purpose of the audit team's work, and to make initial requests for basic information about the facility. The main contacts at the facility for the audit team were Mr. Edvardas Azlaukas and Alfredas Samerdokas who are responsible for the energy use of the plant. We also met with the Technical Director, Mr. Algirdas Joudkazis. In addition, we discussed specific audit issues with the key plant personnel for each area audited. The audit team met with a Ministry of Energy representative, Mr. Edvardas Vazgela. Virginijus Buciunas of NEGA W., a private contractor, assisted with equipment selection during the audit and will continue to assist with the audits as necessary regarding further equipment selection and compatability.

During the first part of the audit the key issues were discussed and a short tour of the facility was performed. The second part included using various auditing instrumentation to collect important energy efficiency information and focused on discussions with various plant personnel. After the information collected was analyzed, the short- and long-term recommendations were formulated and presented to the facility staff.

3.1 Summary

From the discussions held with the plant personnel, the key energy areas within the plant were identified and, the main problems related to energy efficiency from the plants perspective were presented. The areas identified were as follows:

- Combustion control of boilers
- Accurate steam and gas metering
- Control of chilled water use
- Use of heated water for boiler make-up water.

The facility personnel are aware of the primary inefficiencies in their plant and, given the right instrumentation, are technically capable of determining the energy losses. They are also in the best position to determine the proper projects to undertake given the other factors of production such as labor costs, material costs and long-term business plans. Therefore, the audit focused on determining the most appropriate instrumentation available for obtaining accurate measurements that an in-depth energy evaluation would require, and the type of technical information they may require to make long-term energy efficiency decisions such as the replacement of boiler controls. The main areas that the audit addressed were:

- Steam Boiler Area
- Production Areas

- Compressor Room
- Milk factory.

3.2 Steam Boiler Area

As was already mentioned, the three boilers use 99% of the total gas consumption. Therefore, the audit focused on this area to identify energy efficiency opportunities for gas. During the initial inspection of the boilers, the gas consumption and steam production were recorded. During this inspection it was noted that the steam energy produced exceeded the incoming energy of the natural gas indicating a serious problem in the accuracy of the existing meters.

The combustion analyzer was used in a subsequent inspection of the boiler area. The raw data for these readings are in **Appendix A.** See Photograph One in **Appendix B.** The results of these tests are summarized in *Table 3.*

Table 3. Combustion Analysis Results

Boiler	Fuel	T (stack)	02%	CO (ppm)	Ex. Air	EFF
#1	Gas	143 °C	9.0	1659	67%	83%
#2	Gas	139 °C	13.3	0	156%	79%
#3	Gas	126 °C	9.6	0	75%	82%

These readings were the initial readings taken on the boilers after the economizer. Other readings were made before the economizer and after adjustments were made to the fuel-to-air ratio. The measurements taken before the economizer had lower percent oxygen values. This indicates that there is air leaking into the duct reducing the exhaust temperature and the effectiveness of the economizer.

During the audit combustion tests on boiler #2, the air was reduced to decrease the excess air. The excess air was reduced from 94% to 51%. This resulted in a 4.7% increase in efficiency. At this combustion air level there was no unburned carbon monoxide, but as the air was reduced further to 31% excess air, carbon monoxide concentration was high. Therefore, for this boiler the excess air could not be reduced lower than 50%.

Also in the boiler area were the steam meters, gas meters, and main headers for steam and thermal water distribution. The plant staff was not confident in the accuracy of these meters. Temperature measurements were taken of steam and the thermal water piping to

assist in determining proper insulation levels. The appropriate increase in insulation will be discussed later.

3.3 Production Areas

The main production areas of the plant were investigated for energy conservation opportunities. The production areas are the following:

- Preparation
- Glazing
- Cocoa Candy
- Caramel Boiling
- Wafer Production
- Popcorn
- Syrup Boiler
- Caramel Hard Cover.

See Photograph Two in **Appendix B.** In the preparation area there are two 75 kW and five 55 kW motors that are used in mixing. The usual operation of these rollers is to operate three motors for two eight hour shifts. In glazing there is also a 75 kW motor for mixing that is used exclusively for two or three hours in the morning. A demand control opportunity appears to exist just between these two areas if production considerations can be satisfied.

In the cocoa candy and berry caramel area chilled water is required during the production process. Although the area was not in production at the time of the walk through, the chilled water was flowing through the pipes providing unnecessary cooling.

3.4 Compressor Room

There were many areas in the plant that used cooling water. Some of the cooling water was from the chillers and some was just city water. The chillers are ammonia reciprocating chillers. The control of the chillers is basically on and off control with little ability to modulate the chiller for part loads. The cooling tower used with the chillers has two 30 kW draw through fans. The condenser temperature at the time was about 90 °C, even though outside temperatures were well below this temperature.

The control of the chillers should be reviewed to determine the possibility of adjusting the condenser temperature as outdoor air temperature varies. Decreasing the condenser termperature (by decreasing the head pressures) will reduce the amount of power required for a given amount of cooling.

3.5 Milk Factory

Because the Milk plant is the Sweets plant's main steam user, the Milk plant was visited to investigate opportunities for mutual conservation. Some of the steam sold to the Milk plant is then resold to the Bakery. The steam bill to the bakery is one third the total use charged to the Milk plant. This is constant and is based on the size of the steam pipes going into the Milk and Bakery plants. This type of allocation, although probably the best method available, does not promote accountable energy use and, therefore, energy reduction. Steam meters in this area would be beneficial to motivate steam energy saving strategies.

The Milk plant uses 80% of the steam to pasteurize the milk with .7 bar steam. The reduction of steam from the incoming pressure of 13 bar to .7 bar is a significant waste of energy, but at these pressures a turbine would not be appropriate. If other system changes are considered, this aspect should be kept in mind. One type of pasteurization involves the direct injection of steam. If the contract for steam would include credit for the thermal part of the returned condensate to the Sweets plant, it would be economically beneficial for the Milk plant to recover the steam condensate.

A main electric user at the Milk plant is the large ammonia compressors. The increased control of the compressors to reduce head pressures is a long-term conservation measure that the plant should investigate. With reduced head pressures, it may also be necessary to retrofit the expansion valves.

4.0 Summary of Results

As a result of the energy audit, several short- and long-term energy conservation opportunities (ECOs) were identified. Short- term projects are characterized by low or no cost for implementation with short payback periods. These projects could be implemented within two months. Long-term projects are characterized by larger implementation costs and longer payback periods. Short-term energy conservation opportunities identified at the Sweets factory include: boiler combustion control and metering, insulation of piping, and recovery of process cooling water and associated heat. In the long-term, it will be effective for the boiler operations to evolve to a fully automated combustion control system, to add an energy management control system, and to provide better control of the chillers.

The cost of natural gas and the exchange rate are changing so rapidly that it is not possible to predict the cost of fuel in rubles. Therefore, the energy savings is calculated based on nominal world energy prices. Lithuania is in the process of trying to bring fuel prices in line with world prices. For the purpose of this analysis, the cost of natural gas is assumed to be $3.00 per million BTU or $105.00 per 1000 normal cubic meters.

4.1 Short-Term Energy Conservation Opportunities

1. Boiler Combustion Control Metering

The plant has three natural gas-fueled steam boilers as shown in *Figure 3*. Each boiler is rated at 15 metric tons and operates at about 12 bar. Typically two boilers are operated and the third is for reserve. The boilers supply saturated steam to the plant and about 75% of the steam is sold to neighboring facilities. Approximately 30% of the condensate is returned from the steam sold while 70% of the condensate is returned from their own use.

The three boilers operate with no combustion gas analysis. The water treatment facility is well maintained and processes approximately 14 metric tons per hour of boiler make-up water. Continuous boiler blowdown is used to preheat boiler make-up water.

The lack of an effective metering system for steam and natural gas causes the boilers to work at low efficiency except when fully loaded. There is no metering of condensate return or of the thermal water sold. The buyers of the steam are satisfied with the estimates made by the Sweets plant staff of the energy delivered to them. Creation of an energy management program to monitor, test and correct the deficiencies will increase the boiler efficiency from an average 72% to an estimated 81%, saving 1.0 million m^3/year of natural gas.

Boiler flue gas energy losses due to high levels of excess air can be reduced by routine monitoring with a combustion analyzer and manual adjustment of the boiler combustion controls. As part of the inspection and training aspect of this project, boiler combustion analysis were conducted using the Enerac 2000 combustion analyzer. Results of the analysis are contained in *Table 3* of **Section 3.2**.

A well maintained boiler should have boiler efficiency over 80%. This corresponds to an excess air of 50% and economizer heat recovery of about 14%. This represents a boiler efficiency improvement of about 9%. It is estimated that the average boiler efficiency of the three boilers is 72% (based on the higher heating value of the gas fuel of 8900 kcal/m^3). With monitoring of excess air resulting in improved combustion control and improved control of boiler loads with better steam metering, it is estimated that the operating efficiency could be improved to 81%.

It is reported that the facility has an annual average boiler output of 21 metric tons/hr for 6000 hr/yr. (Individual boilers are rated at 15 metric tons/hr). Savings are estimated as follows.

Saturated steam temp	190° C
Enthalpy of steam	663.3 Kcal/kg
Enthalpy of makeup water	12.8 Kcal/kg
Enthalpy of condensate	123.7 Kcal/kg
Total heat in steam	1.27E+07 Kcal/hr
Gas at 81% eff.	1765 m^3/hr
Gas at 72% eff.	1932 m^3/hr
Savings, natural gas	167 m^3/hr
For 6000 hrs savings	$105,000/yr

It is recommended that in-situ flue gas measurement devices and accurate steam metering units be installed for each boiler to provide operators with information necessary to improve boiler efficiency. It is also recommended that a new natural gas flow meter be installed to provide accurate fuel utilization data for the boilers. The total estimated cost for this equipment is $23,000. The resulting pay-back period is 3 months based on world prices of energy. The equipment necessary to attain these energy savings will be recommended for purchase and implementation for this

USAID project. Details of the specifications of the recommended equipment are in **Section 4.3**

2. Uninsulated Piping

A number of uninsulated pipes containing thermal water, steam, and condensate were observed. The majority of the plant piping is adequately insulated; however, several areas experience over-heating due to large lengths of uninsulated piping. Ventilation air is required during part of the year to maintain worker comfort. This compounds an inefficient situation by using energy to mitigate the impacts of energy loss. Using pipe surface temperature measurements and unit pipe surface area, the heat loss from the uninsulated pipe was estimated.

Tables 4, 5, 6 and *7* present the results of a heat loss analysis for steam supply, condensate return, thermal water supply, and thermal water return respectively. From the data in these tables, steam supply line insulation of 2 inches of fiberglass insulation pays back in 6 months. Insulation of all types of lines pays back in less than 1.6 years except for thermal water return. Piping such as hot water distribution to space heaters and hot water control valves should all be insulated to reduce heat loss. Reinstallation of insulation after piping repairs should be part of maintenance activities.

Heat loss from hot water distribution space heating lines contribute to the overheating of rooms. When this occurs, plant personnel open windows to provide control. This results in an additional source for heat loss. The observed plant pipe insulation, which consists of mineral wool wrapped with aluminum foil and chicken wire, would be an acceptable insulation system. Additional measurements of exposed lines will be needed to determine the total annual cost and savings to the plant. It is recommended that the factory make a determination of the necessary line insulation lengths and obtain a bid from a local supplier for the insulation improvements to project the actual payback. Additionally, radiators should be equipped with individual self-contained thermostatically controlled valves.

3. Cooling Water Recovery

Purchased municipal water is used to provide process cooling in some of the production equipment. Water enters the plant at approximately 10 °C and is dumped into the sewer at approximately 30 °C at the rate of 14 metric tons per hour. The boiler requires approximately 14 metric tons per hour of make-up water that is also purchased from the city at the rate of 4.13 Rubles per ton. At world energy prices, the lost energy in the cooling water is approximately 7 Rubles per ton for a total cost of 11.13 Rubles per ton or 156 Rubles per hour. The municipal water is available from the city at only 4000 hr/yr. At 4000 production hours per year this amounts to

624,000 Rubles per year or $6933 per year (at an exchange rate of 90 R/$1). Based on US costs it is estimated that a line could be installed from the point of draining the water into the sewer to the boiler house, a distance of approximately 300 feet, for $6000. This will result in a pay back of less than one year. If this work is done by local contractors at local costs it is expected that the payback period would be much less than a year. It is recommended that the factory proceed with this project using their own funding.

Table 4. Insulation Thickness for Steam Supply Line

..INSULATION ECONOMIC THICKNESS.. DATE 01-03-1992 TIME 13:58:19

*** INPUTS ***

1.	PROJECT NAME		SWEETS
2.	RUN IDENTIFICATION		STEAM SUPP
3.	AMBIENT TEMP,	F	75
4.	FLUID TEMP,	F	320
5.	FUEL COST,	$/MILLION BTU	3
6.	ANNUAL INFLATION, FUEL COST,	%	5
7.	BOOK VALUE OF STEAM PLANT,	$	0
8.	INTEREST RATE,	%	10
9.	AVG HEAT TO PROCESS,	MMBTU/HR	3
10.	SCHEDULE,	HOURS PER YEAR	6000
11.	REMAINING LIFE,	YEARS	10
12.	INSULATION TYPE		FIBER GLASS
13.	CITY COST MULTIPLIER		1
14.	SYSTEM COMPLEXITY		AVERAGE
15.	2''MTRL (2'' PIPE,$/FT) OR (FLAT,$/FT2)		3
16.	INSTALLATION LABOR RATE,	$/HR	15
17.	PIPE SIZE,	IN	3
18.	BOILER EFFICIENCY,	%	72

....RESULTS.....

AVERAGE FUEL COST, $/MMBTU: HEAT @ 5.54 + COST PLANT @ 0

CONDUCTIVITY, BTU-IN/HR-SF-F: .304 AT AVG INSUL TEMP, F: 172.5F

CAPITAL RECOVERY FACTOR AND INFLATION AVERAGING FACTOR: 0.163 AND 1.211

NO OF LAYER	THCKNSS INCHES	MTRL $/FT	LABOR $/FT	TIC $/FT	TIC $/FTYR	HEATLOSS BTU/HR-FT	HEATLOSS $/FTYR	TOTAL $/FTYR	SURF TMP,F
0	0	0	0	0.0	0.0	465	15.5	15.5	
1	1	2	3	4.6	0.8	52	1.7	2.6	103
1	1.5	3	3	5.7	1.0	41	1.4	2.4	93
1	2	4	3	7.2	1.3	34	1.1	2.4	88
1	2.5	5	3	8.3	1.5	30	1.0	2.5	85
1	3	6	4	9.4	1.7	27	0.9	2.6	83
1	4	9	4	12.9	2.3	23	0.8	3.1	81
2	3	6	5	11.0	2.0	27	0.9	2.9	83
2	4	9	6	14.8	2.7	23	0.8	3.4	81
2	5	12	7	18.8	3.4	21	0.7	4.0	79
2	6	15	8	22.8	4.1	19	0.6	4.7	78

Table 5. Steam Condensate

..INSULATION ECONOMIC THICKNESS.. DATE 01-03-1992 TIME 13:55:57

*** INPUTS ***

1.	PROJECT NAME		SWEETS
2.	RUN IDENTIFICATION		STEAM COND
3.	AMBIENT TEMP,	F	75
4.	FLUID TEMP,	F	270
5.	FUEL COST,	$/MILLION BTU	3
6.	ANNUAL INFLATION FUEL COST,	%	5
7.	BOOK VALUE OF STEAM PLANT,	$	0
8.	INTEREST RATE,	%	10
9.	AVG HEAT TO PROCESS,	MMBTU/HR	3
10.	SCHEDULE,	HOURS PER YEAR	6000
11.	REMAINING LIFE,	YEARS	10
12.	INSULATION TYPE		FIBER GLASS
13.	CITY COST MULTIPLIER		1
14.	SYSTEM COMPLEXITY		AVERAGE
15.	2" MTRL (2" PIPE,$/FT) OR (FLAT,$/FT2)		3
16.	INSTALLATION LABOR RATE,	$/HR	15
17.	PIPE SIZE,	IN	3
18.	BOILER EFFICIENCY,	%	72

....RESULTS.....

AVERAGE FUEL COST, $/MMBTU: HEAT @ 5.54 + COST PLANT @ 0

CONDUCTIVITY, BTU-IN/HR-SF-F: .304 AT AVG INSUL TEMP, F: 172.5F

CAPITAL RECOVERY FACTOR AND INFLATION AVERAGING FACTOR: 0.163 AND 1.211

NO OF LAYER	THCKNSS INCHES	MTRL $/FT	LABOR $/FT	TIC $/FT	TIC $/FTYR	HEATLOSS BTU/HR-FT	HEATLOSS $/FTYR	TOTAL $/FTYR	SUR TMP,F
0	0	0	0	0.0	0.0	465	15.5	15.5	
1	1	2	3	4.6	0.8	52	1.7	2.6	103
1	1.5	3	3	5.7	1.0	41	1.4	2.4	93
1	2	4	3	7.2	1.3	34	1.1	2.4	88
1	2.5	5	3	8.3	1.5	30	1.0	2.5	85
1	3	6	4	9.4	1.7	27	0.9	2.6	83
1	4	9	4	12.9	2.3	23	0.8	3.1	81
2	3	6	5	11.0	2.0	27	0.9	2.9	83
2	4	9	6	14.8	2.7	23	0.8	3.4	81
2	5	12	7	18.8	3.4	21	0.7	4.0	79
2	6	15	8	22.8	4.1	19	0.6	4.7	78

Table 6. Thermal Water Supply

..INSULATION ECONOMIC THICKNESS.. DATE 01-03-1992 TIME 13:55:[illegible]

*** INPUTS ***

1.	PROJECT NAME		SWEETS
2.	RUN IDENTIFICATION		THR WAT S
3.	AMBIENT TEMP,	F	75
4.	FLUID TEMP,	F	140
5.	FUEL COST,	$/MILLION BTU	3
6.	ANNUAL INFLATION, FUEL COST,	%	5
7.	BOOK VALUE OF STEAM PLANT,	$	0
8.	INTEREST RATE,	%	10
9.	AVG HEAT TO PROCESS,	MMBTU/HR	3
10.	SCHEDULE,	HOURS PER YEAR	6000
11.	REMAINING LIFE,	YEARS	10
12.	INSULATION TYPE		FIBER GLASS
13.	CITY COST MULTIPLIER		1
14.	SYSTEM COMPLEXITY		AVERAGE
15.	2 MTRL (2" PIPE,$/FT) OR (FLAT,$/FT2)		3
16.	INSTALLATION LABOR RATE,	$/HR	15
17.	PIPE SIZE,	IN	3
18	BOILER EFFICIENCY,	%	72

...RESULTS.....

AVERAGE FUEL COST, $/MMBTU: HEAT @ 5.54 + COST PLANT @ 0

CONDUCTIVITY, BTU-IN/HR-SF-F: .262 AT AVG INSUL TEMP, F: 107.5F

CAPITAL RECOVERY FACTOR AND INFLATION AVERAGING FACTOR: 0.163 AND 1.211

NO OF LAYER	THCKNSS INCHES	MTRL $/FT	LABOR $/FT	TIC $/FT	TIC $/FTYR	HEATLOSS BTU/HR-FT	HEATLOSS $/FTYR	TOTAL $/FTYR	SURF TMP,F
0	0	0	0	0.0	0.0	114	3.8	3.8	
1	1	2	3	4.6	0.8	15	0.5	1.3	83
1	1.5	3	3	5.7	1.0	12	0.4	1.4	80
1	2	4	3	7.2	1.3	10	0.3	1.6	79
1	2.5	5	3	8.3	1.5	9	0.3	1.8	78
1	3	6	4	9.4	1.7	8	0.3	1.9	77
1	4	9	4	12.9	2.3	7	0.2	2.5	77
2	3	6	5	11.0	2.0	8	0.3	2.2	77
2	4	9	6	14.8	2.7	7	0.2	2.9	77
2	5	12	7	18.8	3.4	6	0.2	3.6	76
2	6	15	8	22.8	4.1	5	0.2	4.3	76

Table 7. Thermal Water Return

..INSULATION ECONOMIC THICKNESS.. DATE 01-03-1992 TIME 13:51:53

*** INPUTS ***

1.	PROJECT NAME		SWEETS
2.	RUN IDENTIFICATION		THR WAT R
3.	AMBIENT TEMP,	F	75
4.	FLUID TEMP,	F	110
5.	FUEL COST,	$/MILLION BTU	3
6.	ANNUAL INFLATION, FUEL COST,	%	5
7.	BOOK VALUE OF STEAM PLANT,	$	0
8.	INTEREST RATE,	%	10
9.	AVG HEAT TO PROCESS,	MMBTU/HR	3
10.	SCHEDULE,	HOURS PER YEAR	6000
11.	REMAINING LIFE,	YEARS	10
12.	INSULATION TYPE		FIBER GLASS
13.	CITY COST MULTIPLIER		1
14.	SYSTEM COMPLEXITY		AVERAGE
15.	2'' MTRL (2'' PIPE,$/FT) OR (FLAT,$/FT2)		3
16.	INSTALLATION LABOR RATE,	$/HR	15
17.	PIPE SIZE,	IN	3
18.	BOILER EFFICIENCY,	%	72

...RESULTS.....

AVERAGE FUEL COST, $/MMBTU: HEAT @ 5.54 + COST PLANT @ 0

CONDUCTIVITY, BTU-IN/HR-SF-F: .252 AT AVG INSUL TEMP, F: 92.5F

CAPITAL RECOVERY FACTOR AND INFLATION AVERAGING FACTOR: 0.163 AND 1.211

NO OF LAYER	THCKNSS INCHES	MTRL $/FT	LABOR $/FT	TIC $/FT	TIC $/FTYR	HEATLOSS BTU/HR-FT	HEATLOSS $/FTYR	TOTAL $/FTYR	SURF TMP.F
0	0	0	0	0.0	0.0	54	1.8	1.8	
1	1	2	3	4.6	0.8	8	0.3	1.1	79
1	1.5	3	3	5.7	1.0	6	0.2	1.2	78
1	2	4	3	7.2	1.3	5	0.2	1.5	77
1	2.5	5	3	8.3	1.5	5	0.2	1.6	77
1	3	6	4	9.4	1.7	4	0.1	1.8	76
1	4	9	4	12.9	2.3	3	0.1	2.4	76
2	3	6	5	11.0	2.0	4	0.1	2.1	76
2	4	9	6	14.8	2.7	3	0.1	2.8	76
2	5	12	7	18.8	3.4	3	0.1	3.5	76
2	6	15	8	22.8	4.1	3	0.1	4.2	76

4.2 Long-Term Energy Conservation Opportunities

The long-term measures discussed in this section are more complex, typically more costly, and involve a more in depth engineering and economic analysis with the inclusion of production factors other than energy. The long-term measures recommended are to automate the control of the compressors for optimal efficiency, to use an energy management system to control demand and thermal loads, and to provide better control of the chillers to reduce power consumption particularly during part load conditions.

1. Automate Boiler Combustion Control

This measure involves using the readings of the oxygen sensors recommended in this project to provide an input in adjusting the fuel to air ratio to maximize combustion efficiency. This will involve the retrofit of their existing controls that are based on a linear dependence of the gas flow with the combustion air pressure. It may be necessary to vary gas and air flow independently to meet a less linear condition. It also may be necessary to replace the gas burners providing lower levels of combustion air while still maintaining negligible carbon monoxide concentrations.

2. Energy Management System

The Sweets factory has a very low electric load factor of about 33 percent. The result is that the average cost per kilowatt hour is 0.093 Rubles when the energy charge is 0.051 Rubles per kilowatt hour. Forty-five percent of their electric cost is due to the capacity charge of 10 Rubles per kilowatt per month. A review of a representative daily load profile, *Figures 13, 14* and *15* indicates that it may be possible to shift approximately 400 kilowatts of demand that occurs during the peak period. This would result in a savings of 4,000 Rubles per month or 48,000 Rubles annually. A typical demand charge in the US is $10.00 per kilowatt per month which would result in a savings of $48,000 per year at US energy costs.

Additionally, a large number of process equipment units requiring steam, thermal water, and chilled water are thermally conditioned 24 hours per day so that they are available for immediate start-up at the beginning of the shift. Controlled shut-off valves connected to the energy management system could be installed such that the thermal conditioning could be shut off at the end of shifts and start automatically in sufficient time for the start of the next day's shift.

Coordination with the Production Department will be necessary to determine which electrical equipment would be amenable to controls. The same is true for the control valves on steam and water lines for process equipment. There is not sufficient time to conduct these discussions while the audit team was on-site. The potential energy and cost savings were identified to the plant energy staff.

3. Improve Chiller Controls

With many chiller systems it is possible to float the head pressure of the chillers during periods where the winter weather permits the lower condenser temperatures. It may be necessary to include a pump in the refrigeration line to accommodate the required pressure for the expansion valve. Energy also can be reduced by replacing the thermostatic expansion valves with electronic expansion valves that allow the line pressure to be reduced further. This type of system requires a refrigeration engineer to design a system and control scheme to fit the facility's equipment.

4.3 USAID Equipment Specification For Selected ECO

This section describes the specifications for the equipment recommended to this factory for purchase and implementation by USAID. The equipment is designed to improve the boiler efficiency from 72 to 81% by installing combustion monitoring and accurate gas and steam metering. The annual energy savings based on world energy prices would be $105,000 which would result in a payback of about 3 months. Calculations for the energy savings that is expected by the implementation of this equipment and the economic justification for it are in **Section 4.1.**

ECO: Boiler Combustion Control Metering

1. Combustion Analyzer Specification

The combustion analyzer will provide the Sweets factory with the means to monitor the boiler flue gas excess air levels and enable their own boiler technician to adjust the combustion air controls to reduce the excess air level. The analyzer must have the capability to measure oxygen, with calculations for carbon dioxide. It would be beneficial to also measure carbon monoxide within the flue gases. A combustion analyzer that meets the following specifications is suitable for this application.

Measured Parameters:	Flue Gas Concentrations for Oxygen, Carbon Monoxide (optional), and Temperature
Calculated Parameter:	Flue Gas Excess Air Carbon Dioxide Combustion Efficiency

Analyzer Performance:

Oxygen:	0 to 25% volume +/- 0.1% volume resolution +/- 0.2% volume accuracy
Carbon Monoxide:	0 to 2000 parts per million volume (ppmv) +/- 2 ppmv resolution +/- 5% of reading accuracy
Flue Gas Temperature:	0 to 1100°Centigrade +/- 1 °C resolution +/- 2 °C accuracy
Flue Gas Excess Air:	0 to 1000% +/- 1% resolution +/- 10% accuracy

The estimated cost for three in-situ sensors and the necessary microprocessor read-out equipment is $12,000.

2. Orifice type Steam Meters

An orifice type steam meter is recommended for installation at each boiler and steam supply lines to the factory and for sale of steam. The meter is going to be used in five steam lines and will require only one microprocessor read-out device, but should feed to a hard copy strip chart recorder.

Steam Meters for Boilers: (All three boilers, same)

- Inside Diameter: 150 mm
- Tmax: 300 °C
- Pmax: 15 bar
- Flow max: 16 tons/hr
- Note: Present orifice size = 77.9205 mm

Steam Meter for Milk plant supply:

- Inside Diameter: 150 mm
- Tmax: 300 °C
-

- Pmax: 15 bar
- Flow: 20 tons/hr
- Note: Present orifice size = 92.145 mm

Steam Meter for Sweets plant supply:

- Inside Diameter: 150 mm
- Tmax: 300 °C
- Pmax: 15 bar
- Flow: 16 tons/hr
- Note: Present orifice size = 82.586 mm

In general, the operating parameters for the steam system are the following:

- The temperature of the steam ranges from 140 to 190 °C.
- The pressure of the steam ranges form 6 to 15 bar.
- The flow rate of the steam ranges from 5 to 20 metric tons/h.

The supplier shall provide the correction factor when the meter is installed to five steam lines having different operating conditions (mentioned above). This means a separate pressure reading is required to compensate the flow measurements for varying pressures.

The meter should provide output indicating temperature in °C, pressure in bar, and flow rate in ton/h with the flow totalizer. The standard condition is 20°C and atmospheric pressure. The local power supply is 220/380 volt and 50 hertz.

3. Boiler Natural Gas Meter

The temperature of the natural gas fuel ranges from 0 to 20 °C. The pressure of the natural gas is minimum of about .3 bar. The range of flow of the natural gas is 200 m^3/hr - 3000 m^3/hr. The inside diameter of the gas pipe to the boilers is 100 mm. The flanges at two ends of the meter may require local retrofitting. It is preferable to have the meter be an insertion type, but durability issues may make this impossible. It will be necessary to compensate the flow readings for changes in the gas pressure. The meter is planned to be installed permanently in the gas line with the microprocessor flow totalizer.

The approximate cost is $5,200.

4. Microprocessor with Hard copy Recording

The gas and steam meters will need to be linked to a microprocessor that will include a hard copy recording device such as a strip chart. It may be an integrated system, but will need to compensate the various flow readings for changes in system pressure.

5.0 Plant Management Organization/Recommendation

Our discussions with plant management indicate that energy conservation measures do not have high priority in the Sweets plant. This appears to be due to a lack of finances and a lack of materials. There also appears to be a problem with prioritizing projects and available resources. Major production improvement projects are attractive, while potentially good energy cost saving low-cost/no-cost projects go unattended. The current organization does not lend itself to promoting energy efficiency projects.

It is recommended that the organizational structure be altered to focus efforts on developing justifiable priorities for energy conservation projects. The Chief Energy Manager should have an energy engineer directly responsible for investigating and justifying energy cost cutting projects. With this focus, a long-term plan can be developed and projects economically justified for consideration by the Chief of Mechanics. This energy engineer should also report to the Principal of the Mechanical Section that is responsible for the electric system. This will tie the gas and electric energy efficiency opportunities together for all energy sources.

APPENDIX A
Combustion Analyzer Boiler Readings

BOILER #1 AFTER ECONOMIZER
10.8 METRIC TON/HR

SERIAL # 11100046

ENERAC MODEL 2000

COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 16:17:41
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	82.5	%
AMBIENT TEMPERATURE:	34	°C
STACK TEMPERATURE:	143	°C
OXYGEN:	09.0	%
CARBON MONOXIDE:	1659	PPM
CARBON DIOXIDE:	06.7	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	67	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #1 BEFORE ECONOMIZER
10.8 METRIC TON/HR

SERIAL # 11100046

ENERAC MODEL 2000

COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 16:09:24
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	76.9	%
AMBIENT TEMPERATURE:	34	°C
STACK TEMPERATURE:	282	°C
OXYGEN:	03.4	%
CARBON MONOXIDE:	2595	PPM
CARBON DIOXIDE:	09.9	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	17	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #2 AFTER ECONOMIZER

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:21:44
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	78.8	%
AMBIENT TEMPERATURE:	26	°C
STACK TEMPERATURE:	139	°C
OXYGEN:	13.3	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	04.3	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	156	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #2 BEFORE ECONOMIZER

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:30:38
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	64.1	%
AMBIENT TEMPERATURE:	28	°C
STACK TEMPERATURE:	356	°C
OXYGEN:	10.7	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	05.7	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	94	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #2 BEFORE ECONOMIZER AFTER ADJUSTMENT

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:35:57
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	68.8	%
AMBIENT TEMPERATURE:	29	°C
STACK TEMPERATURE:	353	°C
OXYGEN:	07.8	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	07.5	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	51	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #2 BEFORE ECONOMIZER AFTER ADJUSTMENT

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:54:17
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	71.3	%
AMBIENT TEMPERATURE:	32	°C
STACK TEMPERATURE:	352	°C
OXYGEN:	05.5	%
CARBON MONOXIDE:	OVER	PPM
CARBON DIOXIDE:	08.7	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	32	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #3 AFTER ECONOMIZER

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 14:54:29
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	82.4	%
AMBIENT TEMPERATURE:	22	°C
STACK TEMPERATURE:	126	°C
OXYGEN:	09.6	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	06.4	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	- 01.1	
EXCESS AIR:	75	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #3 BEFORE ECONOMIZER

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:09:14
DATE: 12/10/91

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	71.2	%
AMBIENT TEMPERATURE:	24	°C
STACK TEMPERATURE:	300	°C
OXYGEN:	08.4	%
CARBON MONOXIDE:	3	PPM
CARBON DIOXIDE:	07.1	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	60	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

BOILER #3 BEFORE ECONOMIZER AFTER ADJUSTMENT

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:14:31
DATE: 12/10/91

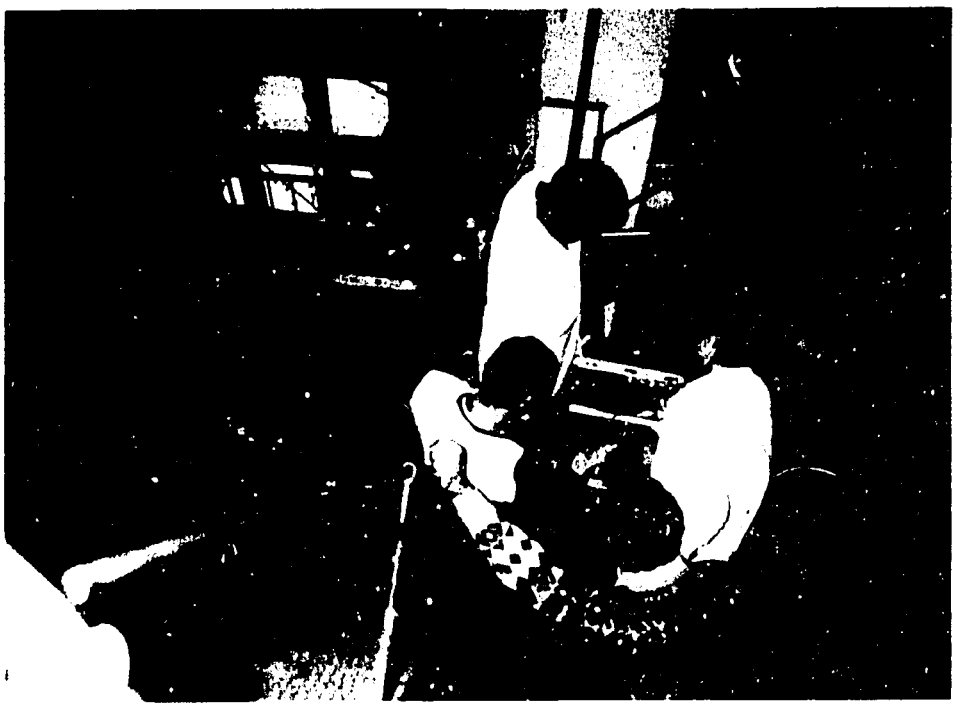
FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	71.8	%
AMBIENT TEMPERATURE:	25	°C
STACK TEMPERATURE:	319	°C
OXYGEN:	06.8	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	08.0	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	44	%

CARBON MONOXIDE ALARM: 50 PPM

E:PPM OXY_REF=TRUE%

APPENDIX B
Photographs



1. ENERAC Testing. From top going clockwise: Mr. Edvardas Azlaukas (Energy Manager), two representatives from the Inspectorate, the Thermal Chief, and the Energy Engineer.

2. Factory workers making sweets.

APPENDIX C
List of Abbreviations

AC	= alternating current
amps	= amperes
atm	= atmosphere = 14.696 pounds per square inch
bar	= 100,000 pascals = 14.504 pounds per square inch
BTU	= British thermal unit
cfm	= cubic feet per minute
cm	= centimeter = 0.3937 inches
cm^2	= square centimeter = 0.155 square inches
CO	= carbon monoxide
CO_2	= carbon dioxide
DC	= direct current
ECO	= energy conservation opportunities
°C	= degree Celsius T[°C] = 5/9*(T[°F] - 32)
°F	= degree Fahrenheit
f^2	= square feet
f^3	= cubic feet
°R	= degrees Rankine T[°R] = T[°F] + 460
eff	= efficiency
ex air	= excess air
Gcal	= gigacalorie = 1 billion calories = 3.968 million BTU
GJ	= gigajoules = 1 billion joules
gph	= U.S. gallons per hour
gpm	= U.S. gallons per minute
GWh	= gigawatt hours = 1 billion watt hours
H_2	= hydrogen
H_2O	= water
H_2SO_4	= sulfuric acid
hectare	= 10,000 square meters = 2.471 acres
hectoliter	= 100 liters = 26.42 U.S. gallons
Hg	= mercury
hr	= hour
Hz	= hertz = cycles per second
J	= joules
kcal	= kilocalories = 1 thousand calories = 3.968 BTU
kg	= kilogram = 2.2046 pounds
Kgcc	= 7,000 Kcal = 27,776 BTU
kJ	= kilojoules = 1 thousand joules = 0.947813 BTU
km	= kilometer = 0.621 miles
kN	= kilonewton = 1 thousand newtons
kp	= kopeck = 1/100 ruble
kPa	= kilo pascals = 1 thousand pascals = 0.14504 pounds per square inch
kV	= kilovolts = 1 thousand volts
kVA	= kilovolt-amperes
kVAr	= kilovars = 1 thousand volt-amperes (reactive)
kW	= kilowatt = 1 thousand watts
kWh	= kilowatt hour = 1 thousand watt hours

lbs	= pounds
liter	= 0.2642 U.S. gallons = 0.03531 cubic feet
m	= meter = 39.37 inches
m^2	= square meter = 10.76 square feet
m^3	= cubic meter = 35.31 cubic feet
mA	= milliampere = 0.001 amperes
MCal	= megacalorie = 1 million calories
metric ton	= 1 thousand kilograms = 1.1023 U.S. tons
mg	= milligrams
min	= minute
MJ	= megajoules
mm	= millimeter = 0.03937 inches
MM	= millions
MPa	= 1 million pascals = 145.04 pounds per square inch
MVA	= megavolt-amperes
MW	= megawatt = 1 million watts
MWh	= megawatt hours = 1 million watt hours
NG	= natural gas
nm	= nanometer
Nm^3	= cubic meters at standard conditions of temperature and pressure (20°C and 1 atmosphere)
NO_X	= nitrogen oxide
O_2	= oxygen
P	= pressure
PC	= personal computer
ppm	= parts per million
psi	= pounds per square inch
psig	= pounds per square inch (gauge)
R	= ruble
s	= second
SO_2	= sulfur dioxide
sq ft	= square feet
Tcal	= teracalorie = 1 trillion calories = 3.968 billion BTU
tonnes/h	= metric ton/hour = t/h
T	= temperature
V	= volts
VArs	= volt-amps (reactive)
VSD	= variable speed drive
yr	= year